

COSEWIC Status Report

on the

Red Knot *Calidris canutus*

prepared for

COMMITTEE ON THE STATUS OF ENDANGERED WILDLIFE IN CANADA

by

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EXECUTIVE SUMMARY

Species information

The Red Knot (*Calidris canutus*) is a medium-sized shorebird with a typical “sandpiper” profile: long bill and smallish head, long tapered wings giving the body an elongated streamlined profile, and longish legs. In breeding plumage, knots are highly distinctive, with face, neck, breast and much of the underparts coloured a rufous chestnut red. Feathers on the upperparts are dark brown or black with rufous and grey, giving the back a spangled appearance. In winter plumage, knots are much plainer, with white underparts and pale grey back. Six subspecies are currently recognized worldwide, all of which form distinct biogeographical populations differing in distribution and scheduling of the annual cycle. Subspecies occurring in Canada include *C. c. rufa*, *C. c. roselaari*, and *C. c. islandica*.

Distribution

C. c. rufa breeds in the central Canadian Arctic and winters in Tierra del Fuego at the southern tip of South America. *C. c. roselaari*, which for the purposes of this report is divided into three subpopulations, includes a Pacific population that winters in California and northwest Mexico and breeds in northern Alaska, passing through western Canada on migration, and two populations wintering in Florida/SE US and Maranhão, Brazil, respectively, that likely breed in central and western parts of the Canadian Arctic. The Florida and Maranhão populations clearly form separate biogeographic populations from the Pacific *roselaari* and the southern South American *rufa* populations; their taxonomic status is currently under revision. *C. c. islandica* breeds in the northeastern Canadian High Arctic (and in Greenland) and winters in areas on the European seaboard.

Habitat

In the Arctic, knots nest on barren habitats such as windswept ridges, slopes, or plateaus, often with less than 5% vegetation. On migration and wintering areas, knots use coastal areas with extensive sandflats (sometimes mudflats), where the birds feed on bivalves and other invertebrates. They are also known to use peat banks, salt marshes, brackish lagoons, mangrove areas, mussel beds, and in South America, *restingas*, which are rocky intertidal platforms with a rich invertebrate fauna.

Biology

Knots are monogamous, with pairs usually laying a single clutch of four eggs, in the latter half of June, with the eggs hatching around mid July. Females depart soon thereafter, leaving the males to accompany the young until they can fly. Breeding success varies considerably from year to year, depending on weather and the abundance of predators, which itself varies over a 3-4 year cycle depending on the abundance of lemmings.

Population sizes and trends

The current population size for *C. c. rufa* is 13,500 – 15,000 adult birds based on counts from the wintering areas in Tierra del Fuego and Patagonia. Surveys from the wintering grounds suggest that the population has decreased by 70% since 1982. Numbers at the major wintering sites in Tierra del Fuego remained fairly steady until 2000, but have since declined dramatically. Few knots now remain at “peripheral” sites along the coast of Patagonia, which held significant numbers in the 1980s. Similar declines have been observed throughout the migration range of *rufa*, confirming an actual population decline rather than a redistribution of the birds to different areas.

The current population size for *C. c. roselaari* knots wintering in Florida/SE US is approximately 3,375 adult birds. This group has declined by about 70% in the last 15 years. Less information is available for the Maranhão population, which may have declined by about 7% over the past 20 years to about 5,700 adults. Available evidence suggests the Pacific population of *roselaari* has also declined by about 60% in the last 15-20 years, with a current population size of 1,500-3,000 adults. The overall decline for the combined population is 47%.

Current *C. c. islandica* populations wintering in Europe now number about 202,500 adults. This represents a decline of about 17% since the late 1990's.

Limiting factors and threats

The single most important threat to *rufa* and *roselaari* knots wintering in Florida/SE US and Maranhão, Brazil has been the overfishing of horseshoe crabs (*Limulus polyphemus*) in Delaware Bay, leading to a decimation in numbers of horseshoe crab eggs, the most important food used during the final spring stopover. Degradation of habitats in areas such as San Francisco Bay and Grays Harbor, WA has likely affected the Pacific coast populations of *roselaari*, while overfishing of shellfish on major wintering areas in the Dutch Wadden Sea have affected *C. c. islandica* wintering in Europe.

Other possible threats include decreased habitat availability during migration in eastern North America (providing few alternative sites for the birds to use), disturbance, increased risk from severe weather events (e.g., hurricanes) during migration, oil and chemical pollution in North and South America, climate change effects including sea level rise and changing conditions on the Arctic breeding grounds, and increased levels of predation from rebounding predator (e.g., falcon) populations.

Special significance of the species

Red Knots have long been regarded as a “flagship” species for shorebird conservation, because of their enormously long, inter-continental migrations and their vulnerability owing to concentration in large numbers (involving a large proportion of the population) at a limited number of key sites. Philosophically, they are a wildlife species shared by

many nations, crossing many international boundaries, and are symbolic of the need for international cooperation for their successful conservation. Conservation of sites used by knots will also benefit many other shorebird species.

Existing protection

Red Knots are protected under the Migratory Birds Convention Act (1917, updated in 1994). A formal status assessment in the US resulted in their being listed as a “candidate species”, indicating they qualified for endangered species status. Knots are listed as Threatened in New Jersey and as of Special Concern in Georgia. They have been added to Appendix I of the Convention on Migratory Species (“Bonn” Convention), which lists species threatened with extinction. NatureServe lists the *rufa* subspecies of Red Knots globally as G4T1, or critically imperiled globally at the subspecies level: national status is N1N, or critically imperiled in its non-breeding range in the USA, and N1B and N1N, or critically imperiled in both breeding and non-breeding range in Canada.

TABLE OF CONTENTS

EXECUTIVE SUMMARY.....	2
SPECIES INFORMATION.....	7
Name and classification.....	7
Morphological description.....	8
Genetic description.....	9
Designatable units.....	12
DISTRIBUTION.....	13
Global range.....	13
Canadian range.....	13
HABITAT.....	18
Habitat requirements.....	18
Habitat trends.....	18
Habitat protection/ownership.....	19
BIOLOGY.....	20
Life cycle and reproduction.....	20
Predation.....	21
Physiology.....	21
Dispersal/migration.....	22
Interspecific interactions.....	23
Adaptability.....	23
POPULATION SIZES AND TRENDS.....	24
Search effort.....	24
Abundance.....	26
Fluctuations and trends.....	29
Rescue effect.....	36
LIMITING FACTORS AND THREATS.....	37
SPECIAL SIGNIFICANCE OF THE SPECIES.....	41
EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS.....	42
TECHNICAL SUMMARY.....	43
ACKNOWLEDGEMENTS.....	50
AUTHORITIES CONSULTED.....	50
INFORMATION SOURCES.....	53
BIOGRAPHICAL SUMMARY OF REPORT WRITERS.....	63

List of tables

Table 1. Estimates of F_{ST} for population differentiation in knots.....	10
Table 2. Recognition/status of key sites used by Red Knots by conservation organizations.....	19
Table 3. Population estimates of the three subspecies of the Red Knot.....	27
Table 4. NatureServe categories for Red Knots <i>rufa</i> subspecies in US States and Canadian Provinces.....	42

List of figures

Figure 1. Worldwide distribution of the six recognized subspecies of the Red Knot.....	8
Figure 2. Adult Red Knot in breeding plumage.....	9
Figure 3. Minimum spanning network diagram showing the relationships between haplotypes from the mitochondrial control region of knots.	11
Figure 4. Observed and expected mismatch distributions of mitochondrial control region sequences in knots.	11
Figure 5. Breeding range of Red Knots in the Canadian Arctic.	14
Figure 6. Predicted locations of nesting habitats of Red Knots based on land cover types in the central Canadian Arctic	16
Figure 7. Important areas for Red Knots in eastern Canada.	17
Figure 8. Population estimates from of Red Knots <i>rufa</i> subspecies in southern South America.....	29
Figure 9. Counts of <i>C. c. rufa</i> at major wintering sites in Tierra del Fuego.....	30
Figure 10. Maximum counts observed during aerial surveys of Red Knots during northward migration in Delaware Bay.....	31
Figure 11. Mean counts of Red Knots observed during southward migration on the east coasts of the USA and Canada.....	32
Figure 12. Predicted population trends of adult <i>rufa</i> Red Knots , juveniles, and the sum of these two age groups	33
Figure 13. Declines of Red Knots subspecies <i>islandica</i> on wintering grounds in the United Kingdom and The Netherlands.....	35

SPECIES INFORMATION

Name and classification

Class: Aves

Order: Charadriiformes

Family: Scolopacidae

Genus: *Calidris*

Species: *canutus* (Linnaeus 1758)

English name: Red Knot; French name: Bécasseau maubèche; Inuktitut name: Qajorlak

Subspecies

Red Knots are currently classified into six subspecies, each with distinctive morphological traits, breeding areas, migration routes and wintering areas, and annual cycles (Piersma and Davidson 1992; Tomkovich 1992, 2001; Piersma and Baker 2000; Piersma and Spaans 2004; Figure 1). Three subspecies occur in Canada. They include *C. c. rufa*, *C. c. roseaari*, and *C. c. islandica*.

C. c. rufa breeds in the central Canadian Arctic and winters in southern Patagonia and Tierra del Fuego.

In this report, *C. c. roseaari* will include three biogeographic populations (see designatable units): i) the Pacific coast population, which breeds in northwest Alaska and on Wrangel Island and migrates down the Pacific coast through Canada and the northwestern US and winters from California to the Pacific northwest region of Mexico, and possibly the Gulf of Mexico; ii) the Florida/SE US population, which likely breeds in Alaska or the western Canadian Arctic and winters in Florida, Georgia and South Carolina and iii) the Maranhão, Brazil population, which likely breeds in Alaska or the western Canadian Arctic and winters in Maranhão, on the north-central coast of Brazil. The three groups clearly form separate biogeographic populations; there is currently uncertainty over the taxonomic status of knots in the Florida and Maranhão populations.

C. c. islandica breeds in the northeastern Canadian High Arctic probably as far west as Prince Patrick Island and south to Prince of Wales Island (Godfrey 1992; Morrison and Harrington 1992) and in the high Arctic of Greenland from the northwest around the north coast to about Scoresby Sound on the east coast: it winters in the U.K. and the Netherlands and migrates to the breeding grounds through Iceland and northern Norway.

C. c. rogersi breeds on the Chukotski Peninsula in eastern Russia and winters in south east Australia and New Zealand.

C. c. piersmai breeds on the New Siberian Islands in north central Russia and winters in northwest Australia.

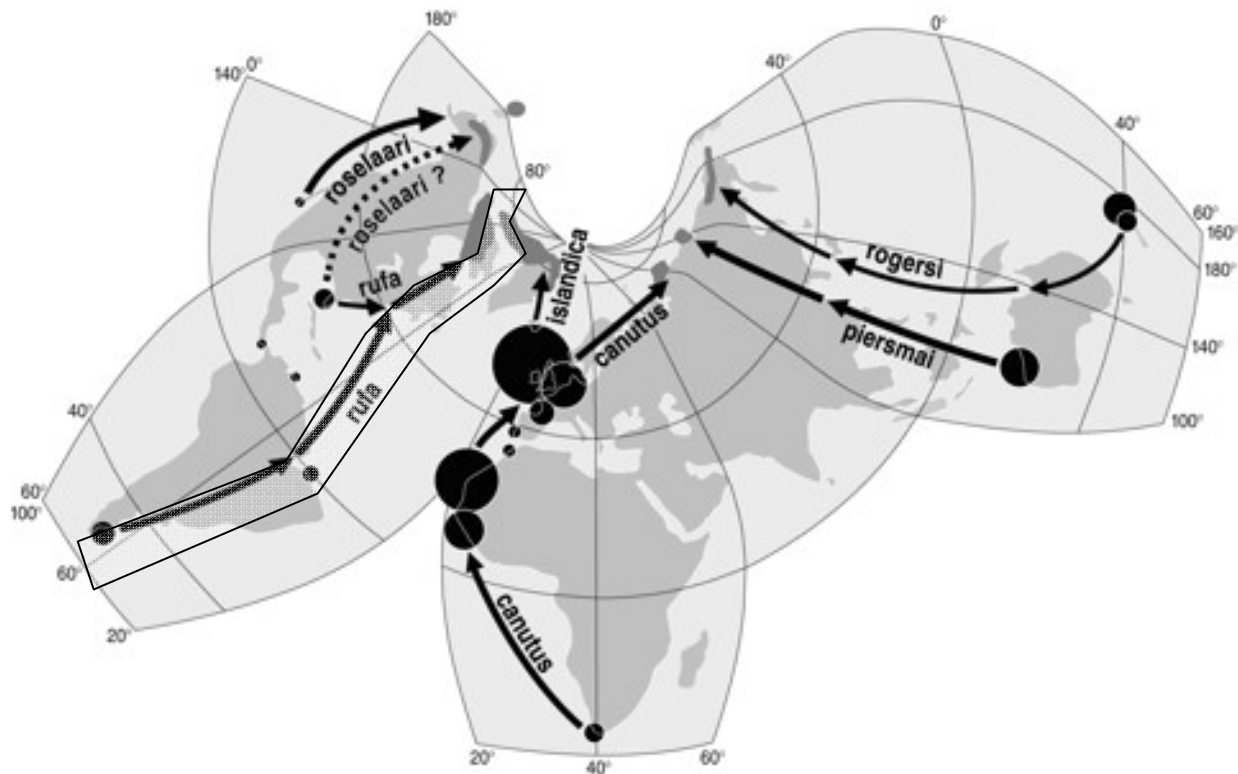


Figure 1. Worldwide distribution of the six recognized subspecies of the Red Knot. Arrows connect non-breeding (“wintering”) areas (dots, scaled to population size) with breeding areas (dark gray shading). Migration system of *rufa* knots between wintering areas in Tierra del Fuego and breeding areas in the central Canadian Arctic is outlined. Note that former wintering populations of *rufa* on the coast of Patagonia in Argentina have almost disappeared, with the bulk of the population currently confined to Tierra del Fuego. (Adapted from a map drawn by Dick Visser, provided by Jan van Gils, see Nilés et al. 2005).

The nominate subspecies *C. c. canutus* breeds on the Taymyr Peninsula in western Siberia and winters in west and south west Africa.

Morphological description

The Red Knot is a medium-sized shorebird with a typical calidridine sandpiper profile: proportionately small head, bill straightish, tapering from thicker base to thinner tip, and not much longer than head; short neck, short tibia, stout tarsus, long tapered wings giving an elongated streamlined profile to the body. It is the largest of the calidridine sandpipers in North America (length 23-25 cm, weight about 135 g though highly variable).

In breeding, or alternate plumage, knots are highly distinctive, with face, neck, breast and much of the underparts coloured a distinctive rufous chestnut-red (Figure 2). The lower belly and vent behind the legs tends to be light, especially in *rufa* compared to the other subspecies, and some whitish or brownish feathers may be scattered through the breast (thought to be more common on females). Feathers on the upperparts have dark

brown-black centres, edged with rufous and grey, giving the bird a spangled appearance that provides a remarkably effective camouflage on the sparsely vegetated High Arctic breeding grounds. Flight feathers range inwards from dark brown/black in the primaries to grey in the secondaries and tail feathers, and there is a narrow whitish wingbar. Males tend to be more brightly coloured than females, with more extensive rufous on the underparts.

In winter, or basic plumage, knots are much plainer, with white underparts and a pale grey back. The upper breast has grayish or brownish streaking, extending laterally along the flanks, and the head has dull grayish patterning with a whitish supercilium.



Figure 2. Adult Red Knot in breeding (alternate) plumage.

Juveniles have similar plumage, but can be distinguished by dark subterminal bands on the feathers of the mantle, scapulars and coverts, giving the bird a characteristic scaly appearance. Juveniles may also have a pale dull buffish colour suffusing the breast.

Knots may be distinguished from the superficially similar dowitchers (*Limnodromus* species) by their shorter bill, paler crown, whitish rump barred with grey (vs a white lower back forming a distinctive “V” in flight in dowitchers), and voice; and from the smaller Dunlin (*Calidris alpina*) by their straighter bill (Dunlin’s appear proportionately longer with a droop at the tip).

Genetic description

Genetic differences among knot subspecies have been investigated by sequencing the fast-evolving control region of the mtDNA molecule (Buehler and Baker 2005). Most haplotypes differed by a single base change, producing a minimum spanning network diagram with a star-like pattern characteristic of a species that has undergone a recent bottleneck with subsequent expansion (Slatkin and Hudson 1991; Figure 3). Despite the apparent lack of sorting of haplotypes into discrete genetic lineages in each subspecies, knots showed low but significant population differentiation using both conventional *F*-statistics and exact tests. Four genetically distinct groups were found, corresponding to *C. c. canutus*, *C. c. piersmai*, *C. c. rogersi* and a North American group containing *C. c. roselaari*, *C. c. rufa* and *C. c. islandica* (Table 1, Pooled Exact test, $P < 0.001$, Buehler and Baker 2005).

Table 1. Estimates of F_{ST} for population differentiation in knots (below diagonal) calculated using mtDNA control region sequences. Above the diagonal “+” indicates significance at the 0.01 level, and – indicates not significant ($P > 0.01$). From Buehler and Baker (2005).

	<i>C.c. canutus</i>	<i>C.c. islandica</i>	<i>C.c. piersmai</i>	<i>C.c. rogersi</i>	<i>C.c. roselaari</i>	<i>C.c. rufa</i>
<i>C.c. canutus</i>	0	+	+	+	+	+
<i>C.c. islandica</i>	0.19	0	+	+	-	-
<i>C.c. piersmai</i>	0.07	0.12	0	+	-	-
<i>C.c. rogersi</i>	0.27	0.20	0.07	0	+	-
<i>C.c. roselaari</i>	0.17	-0.04	0.08	0.15	0	-
<i>C.c. rufa</i>	0.23	0.005	0.07	0.05	0.002	0

Genetic differences between subspecies are also apparent in nuclear DNA. A genomic scan of 836 loci using amplified fragment length polymorphisms (AFLPs) detected different frequencies of the dominant markers at 129 loci, and showed significant genetic differentiation among subspecies ($F_{ST}=0.089$). The genetic distance between *C. c. roselaari* and *C. c. rufa* is small (0.1), but similar to the genetic distance between *C. c. rogersi* (southeast Australia and New Zealand) and *C. c. canutus* (Eurasia).

The demographic history of knot populations can be deduced from the genetic signature in the control region sequences, providing they are selectively neutral which appears to be the case in knots. This can be done by computing the number of mutational differences between each pair of sequences in individual birds. These pair-wise differences in knot subspecies have a single peak pattern that would be expected when a population expands after a recent bottleneck (Avice 2000, Figure 4).

Coalescent modeling of the sequence variation using a rate of molecular evolution calibrated for shorebirds estimated that divergence times of populations representing all six subspecies of knots occurred within the last 20,000 years (95% CI: 5,600 – 58,000 years ago), thus corresponding to the Last Glacial Maximum 18,000 - 22,000 years ago. This basal split separated *C. c. canutus* breeding in central Siberia and migrating to western Africa from a lineage that expanded into eastern Siberia and began to migrate to Australia (the ancestor of *C. c. rogersi* and *C. c. piersmai*).

As the ice retreated, the latter lineage eventually expanded across Beringia into Alaska and established the North American lineage about 12,000 (95% CI: 3,300 – 40,000) years ago. At this time, an ice-free corridor that had opened between the ice sheets covering the Rockies to the west and the Great Plains to the east served as a dispersal route for an assortment of organisms, including humans. This corridor was oriented NW-SE, and may thus have guided the evolution of a new migratory pathway between Alaska or the western Canadian Arctic and the southeast United States. As the ice sheets retreated farther eastwards across the High Arctic of Canada, the ancestral population was fragmented sequentially within the last 5,500 years into three breeding populations, corresponding today to *C. c. roselaari*, *C. c. rufa* and *C. c. islandica*. If this is correct, then the present wintering flocks in the southeast US are properly attributed to *C. c. roselaari* and would be predicted to return annually to their ancestral breeding grounds in Arctic northwest North America. Furthermore, the migration pathways of

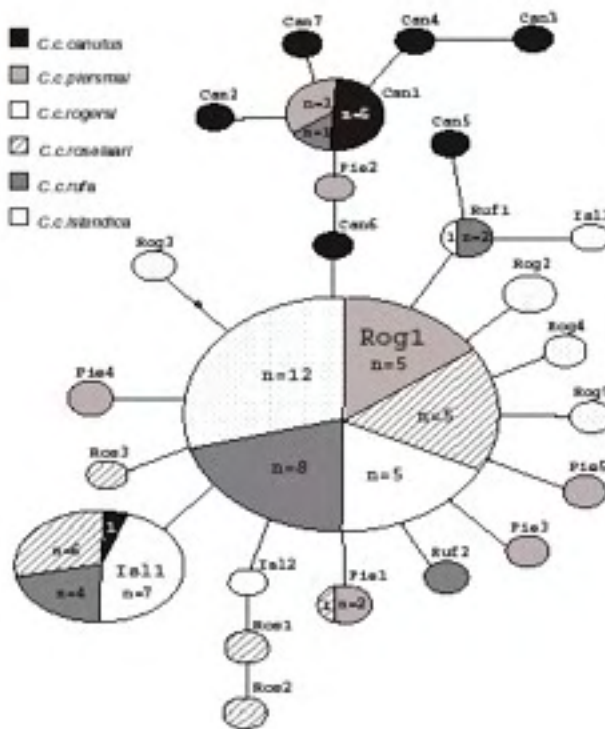


Figure 3. Minimum spanning network diagram showing the relationships between haplotypes from the mitochondrial control region of knots. Ovals represent haplotypes and connecting lines represent a single base pair change between haplotypes. Small open circles on lines represent multiple base pair changes between haplotypes. From Buehler and Baker (2005).

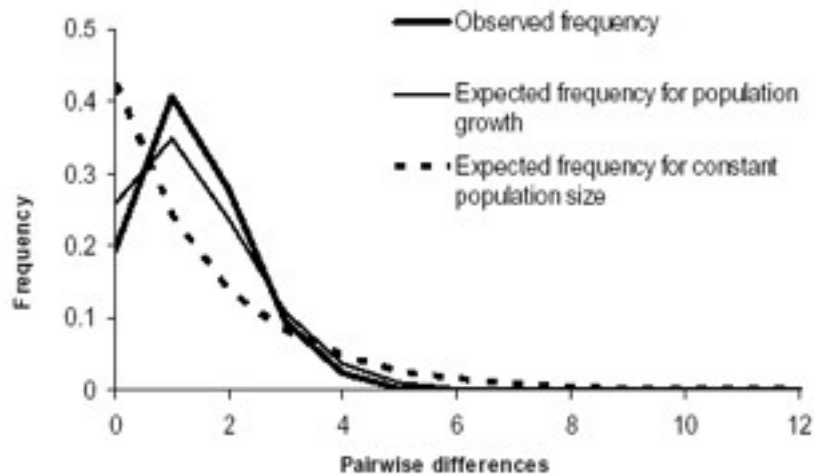


Figure 4. Observed and expected mismatch distributions of mitochondrial control region sequences in knots. Knots closely match the pattern expected under population growth in the recent past. From Buehler and Baker (2005).

C. c. rufa and *C. c. islandica* are newly evolved responses to the eastward expansion of their breeding ranges. The divergence of *C. c. piersmai* and *C. c. rogersi* was estimated to have occurred about 6,500 (95% CI: 1,000 – 23,000) years ago, probably as a consequence of their isolated breeding ranges in the New Siberian Islands and the Chukotski Peninsula in Russia.

Given the recent nature of these divergence times among knot subspecies, it is not surprising that the level of genetic differentiation in the neutral mtDNA sequences and nuclear AFLP is small. There has simply not been enough time for mutations to accumulate in these DNA regions to track evolutionary changes operating in the more immediate scale of ecological time. In such cases, the apparently small genetic differences in neutral DNA sequences should not be misinterpreted in defining subspecies (Avice 1989). Instead, morphological and ecological differences are more likely to reflect adaptive changes that represent responses to positive natural selection. The situation is summarized by Buehler and Baker (2005) thus: “While the six currently recognized subspecies of Red Knots cannot be distinguished by their control region sequences, they are beginning to sort into different lineages and it would be inadvisable to lump them into a single evolutionary unit on genetic grounds alone. Given the passage of time, evolution of neutral genetic markers in Red Knots should catch up with morphological and plumage differences, different migration routes, separate breeding grounds, and different moult schedules to more clearly distinguish subspecies ...”.

Designatable units

This assessment will be based on three designatable units that correspond to the three subspecies of Red Knot that occur in Canada; *C. c. rufa*, *C. c. roselaari* and *C. c. islandica*. Although genetic differences between the three subspecies may be small owing to the relatively short time they have been separated (see above), they occupy widely separated geographic areas (breeding and wintering; Salomonsen 1950; Godfrey 1953, 1986; Morrison 1975), have different migration and life history schedules, differences in morphology and plumage (Conover 1943; Morrison and Harrington 1992; Harrington 2001) and lack interchange between populations (Baker et al. 2005a,b).

The main uncertainty with the assigned designatable units concerns the inclusion of the Florida/SE US and the Maranhão, Brazil populations within *C. c. roselaari*. The taxonomic status of the Florida/SE US population is currently under revision. The genetic evidence suggests, however, that it is closer to *C. c. roselaari* than to *C. c. rufa* (Niles et al. 2005). This population also differs from *rufa* in morphology (Niles et al. 2005) and banding of thousands of birds in the flyway has clearly shown no detectable interchange between the two groups on the wintering grounds (Baker et al. 2005a). For these reasons, we will include the Florida/SE US population of knots with *C. c. roselaari*.

The taxonomic status of the Maranhão, Brazil population is also uncertain. Genetic (Baker et al. 2005a; Niles et al. 2005) and stable isotope evidence (Atkinson et al. 2005) from feathers suggests a closer affinity to the Florida/SE US population than *C. c. rufa*. Also, this population differs from *rufa* in morphology (Baker et al. 2005a; Niles et al.

2005) and migration scheduling. Like the Florida/SE population, there appears to be no interchange between the Maranhão populations and *rufa* wintering in Tierra del Fuego. Given the wide geographic separation from *rufa* wintering in southern South America, the lack of interchange, the relative proximity to more northerly wintering groups in Florida/SE US, and the proposed evolution of migratory patterns based on genetic evidence (see above), we are also assigning the Maranhão birds to the *roselaari* group for the purposes of this status assessment.

DISTRIBUTION

Global range

The global distribution of the six currently recognized subspecies of Red Knots is shown in Figure 1 and described in the subspecies section.

Wintering grounds (outside Canada)

The major wintering areas used by *rufa* knots were discovered in Tierra del Fuego and Patagonia, Argentina and Chile in the 1980s by Morrison and Ross (1989). In the 1980s, sites in Tierra del Fuego and Patagonia held 79% and 21% of the southern wintering population of birds, but by the early 2000s, Tierra del Fuego held about 98% of the total and the “peripheral” sites in Patagonia held only about 2%. The population thus appears to have contracted to the core sites, leaving few birds at the Patagonian sites (Morrison et al. 2004). The major wintering areas used by *roselaari* knots include the i) Pacific coast of the Americas, from California south to Baja California and parts of northwest Mexico around the Gulf of California (Pacific coast population), ii) southeastern US including Florida and Georgia, with smaller numbers in South Carolina and Texas (Florida/SE US population) and iii) Maranhão on the north-central coast of Brazil (Maranhão, Brazil population). *Islandica* knots winter on the European seaboard (Salomonsen 1950; Godfrey 1953, 1986; Morrison 1975).

Canadian range

Breeding grounds

The breeding range of *C. c. rufa* falls entirely within the central parts of the Canadian Arctic, while about 40% of the breeding population of *C. c. islandica* breed in the northeastern Canadian Arctic. Knots breeding in northern and western Alaska and the western Canadian Arctic belong to *roselaari* (Figure 5).

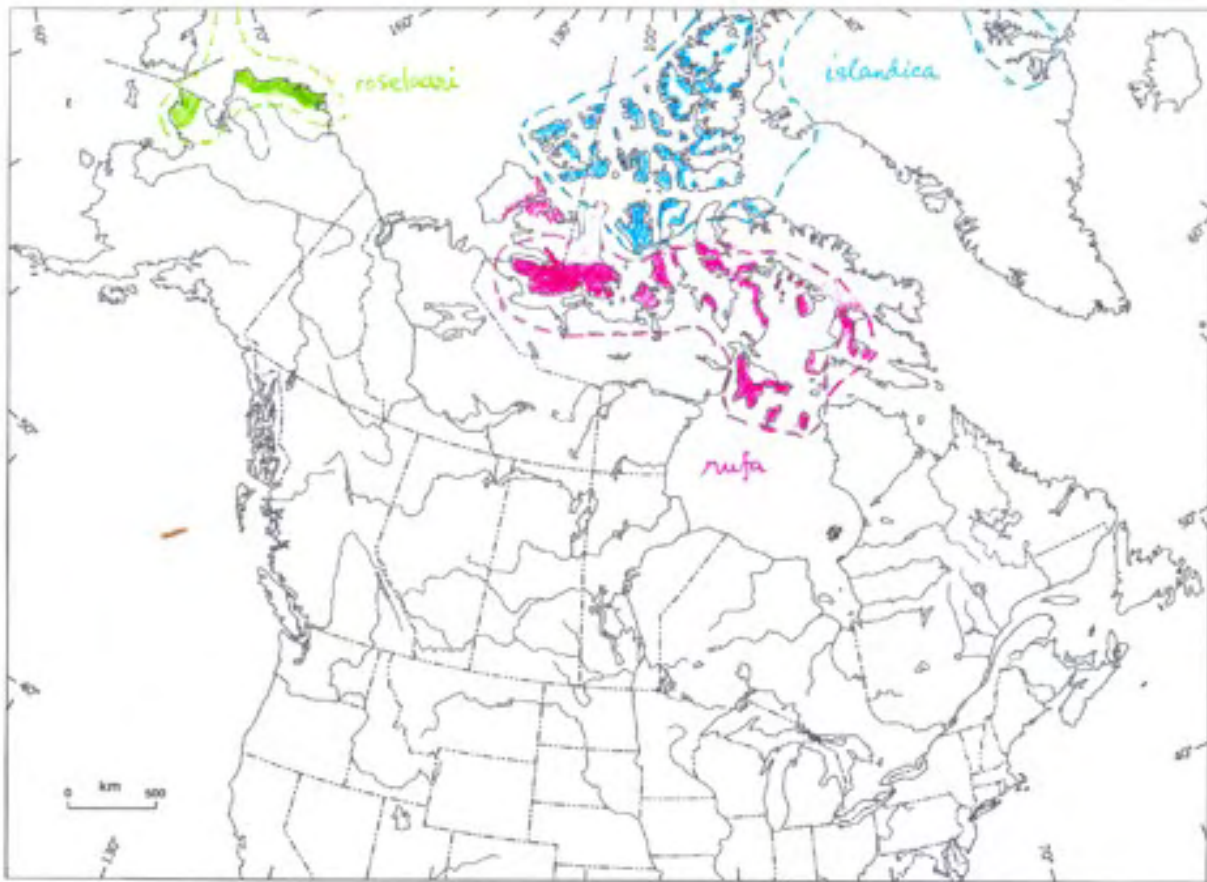


Figure 5. Breeding range of Red Knots in the Canadian Arctic. *C. c. rufa* occupies areas in the Central Canadian Arctic, and breeds entirely within Canada. *C. c. roseolaari* populations wintering in Florida/SE US and Maranhão may share parts of this range, most likely towards the western portion. *C. c. roseolaari* wintering on the Pacific coast of the Americas occupy breeding areas in northwestern Alaska (and Wrangel Island). Knots in the High Arctic regions of northeastern Canada and of Greenland are *C. c. islandica*. Broken lines enclose overall likely range of each subspecies and solid areas represent likely occupied suitable habitat within the range.[To be redrawn for final version of report]

Within the central Canadian Arctic, suitable habitat is not continuous, so there are discontinuities within the range and it appears that not all suitable potential habitat is occupied (Figure 6). *Rufa* breeds on Coats and Mansel islands in northern Hudson Bay, on Southampton Island, on the east coast (Godfrey 1986) as well as the islands of the Foxe Basin (e.g., Prince Charles Island, Rowley Island, but not on Air Force Island (V. Johnston pers. comm. 2005) and the west coast of Baffin Island (RIGM pers. observation; Niles et al. 2005), probably through the Boothia Peninsula area, on King William Island, and on the southern parts of Victoria Island (Parmelee et al. 1967). Suitable habitat does not appear to occur on land between northern Hudson Bay and the Rasmussen Basin (Niles et al. 2005), and the species was not recorded in this area (Godfrey 1986, 1992) or in the Rasmussen Lowlands (Johnston et al. 2000). *Rufa* appears to breed on the west side of the Boothia Peninsula and on King William Island

(Niles et al. 2005), but it is replaced by *islandica* on Prince of Wales Island to the north (Manning and Macpherson 1961; Godfrey 1992). Although there appears to be suitable habitat on Banks Island at the western edge of the Arctic Islands, knots have not been recorded breeding in this area (Manning et al. 1956; V. Johnston pers. comm. 2005).

C. c. roseaari wintering on the Pacific coast of the Americas occupy breeding areas in northwestern Alaska and Wrangel Island. Breeding grounds occupied by Florida/SE US and Maranhão wintering populations are not clearly delineated, but are likely to involve the more westerly parts of the breeding range in Canada. One piece of evidence to support this hypothesis is the recovery of a banded bird wintering in Florida in Manitoba on northward migration. This recovery suggests that it was headed towards the western end of the range as opposed to going up the Atlantic coast to the eastern part of the breeding grounds.

The estimated extent of occurrence (EO) of *rufa* based on a compilation by the Canadian Wildlife Service (A. Baril, pers. comm. 2005) of breeding range maps from NatureServe, WildSpace, and Birds of North America is 205,534 km². The area of occupancy (AO), or area of suitable habitat occurring within this range, is 128,375 km² (97,750 km² <50 km from coast plus 30,425 km² >50 km from coast; based on potential suitable habitat types, see Figure 6, R. Lathrop, pers. comm. 2005). The estimated EO for the Florida/SE US and Maranhão, Brazil populations of *C. c. roseaari* is an unknown portion of the EO (i.e. 205,534 km²) assigned to *rufa* (i.e. it may overlap with some portion of *rufa*'s range) and the EO for the Pacific coast population is 41,396 km², which includes the breeding grounds in Alaska. The AO for the Florida and Maranhão populations is some unknown portion of the AO for *rufa* (i.e. 128,375 km²), while the AO for the Pacific coast population is 25,856 km² based on suitable breeding habitat in Alaska. The estimated EO for *islandica* is 455,669 km², which includes their breeding range in Canada. The AO for *islandica* in Canada is 284,611 km² based on suitable habitat.

Migration

On migration, large numbers of knots pass southwards through the southwest coast of Hudson Bay (Manitoba and Ontario) and west and southern coasts of James Bay during July and August (Ontario) (Hope and Shortt 1944; Manning 1952; Ross et al. 2003). The southeast corner of Akimiski Island also appears to be important for knots. Knots have also been recorded in small numbers (100-350) on the south coast of James Bay in Quebec (Aubry and Cotter 2001a).

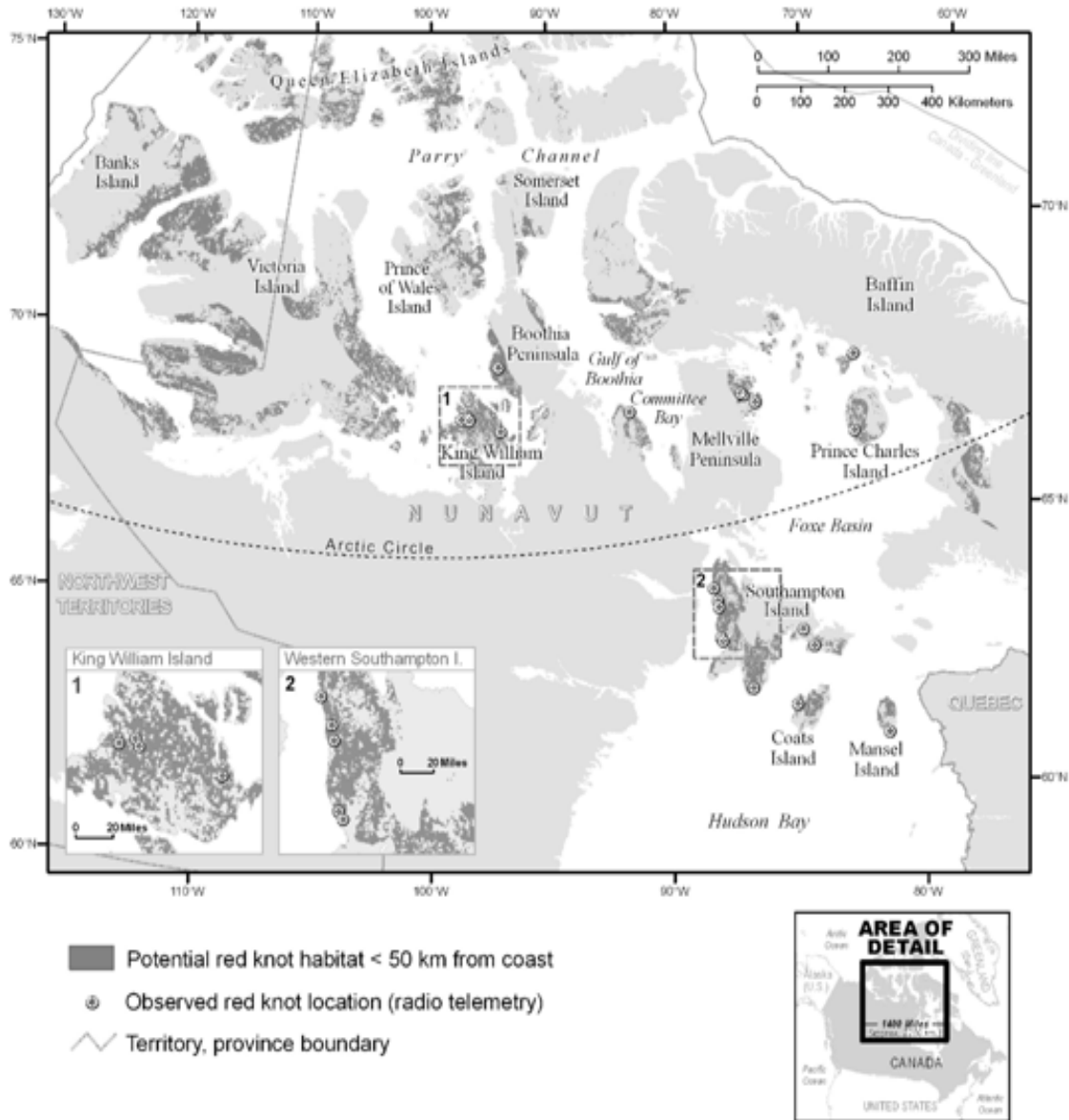


Figure 6. Predicted locations of nesting habitats of Red Knots based on land cover types in the central Canadian Arctic (and point locations [circles] of Red Knots located on the nesting grounds after being radio-tagged in Delaware Bay during northward migration); from Niles et al. (2005).

The most important areas for *rufa* knots on migration in eastern Canada are currently along the north shore of the St. Lawrence River in Quebec (Figure 7). The sightings in the Mingan Islands archipelago in 2006 of many colour-marked birds that had been captured in Argentina confirm the identity of the birds as belonging to the *rufa* population wintering in southern South America (Y. Aubry, pers. comm. 2006). Ouellet (1969) identified four knots collected from a flock of 200 on Anticosti Island as belonging to the *rufa* subspecies.

During northward migration, large flights of knots have been observed passing northwards through southern James Bay at the end of May or start of June (RIGM

unpubl. data), having probably flown directly from Delaware Bay (Morrison and Harrington 1992). Large concentrations are occasionally found around Lake Ontario, though these probably represent weather related dropouts from the main migration (McRae 1982; Weir 1989; see Morrison and Harrington 1992). The sighting of a bird colour-banded at Lagoa do Peixe in southern Brazil at Presqu'île Provincial Park indicates the birds include migrants from the southern *rufa* population.

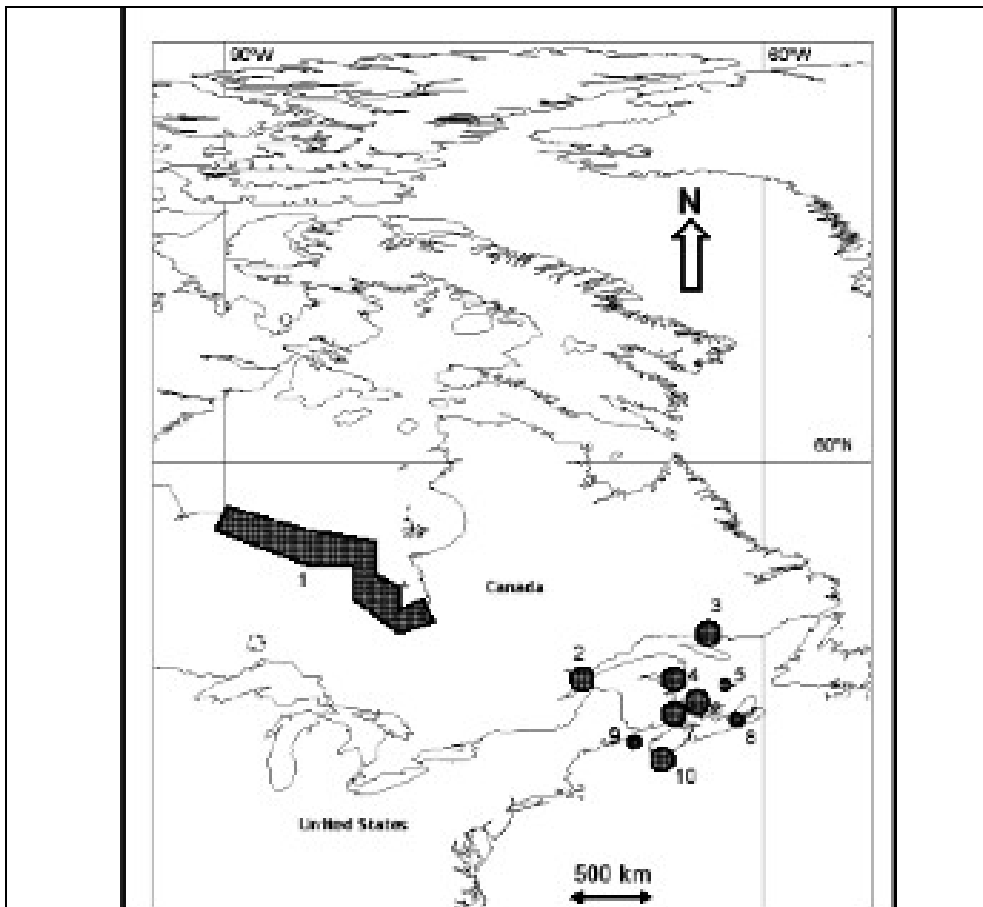


Figure 7. Important areas for Red Knots in eastern Canada. Locations shown on the map are: 1. Southwest coast of Hudson Bay (MB, ON) and west and south coasts of James Bay (ON, QC); 2. Saguenay River mouth, St. Lawrence River, QC; 3. Mingan Archipelago, north shore of St. Lawrence River, QC; 4. Miscou Island, NB; 5. Magdalen Islands, Gulf of St. Lawrence, QC; 6. North shore Prince Edward Island; 7. Upper Bay of Fundy (Mary's Point), NB; 8. southern Cape Breton Island, NS; 9. Grand Manan Island, NB; 10. Cape Sable, NS. (Information compiled from Hope and Shortt 1944; Morrison and Harrington 1979; Morrison et al. 1980; Morrison and Gaston 1986; Hicklin 1987; Aubry and Cotter 2001a; Roberge et al. 2001; Ross et al. 2003; R.I.G. Morrison unpubl. data from Maritimes Shorebird Survey; R.K. Ross and R.I.G. Morrison unpubl. data from Hudson Bay and James Bay aerial surveys, EPOQ database pers. comm. Yves Aubry).

Less information is available to identify migration areas used by *roselaari* wintering in Florida/SE US and Maranhão. Both groups are known to pass through Delaware Bay during the spring. However, a significant proportion of these groups likely migrates to the breeding areas through the interior of North America, as indicated by a band recovery of a bird wintering in west Florida in Manitoba during spring migration. The Pacific coast population of *C. c. roselaari* migrates down the Pacific coast of North America, including through coastal British Columbia.

HABITAT

Habitat requirements

Red Knots use very different habitats for breeding and wintering/migration. In the Arctic, knots nest on barren habitats (often less than 5% vegetation) such as windswept ridges, slopes or plateaus. Nest sites are usually in dry, south-facing locations, and may be located near wetlands or lake edges, where the young are led after hatching. Densities are usually low, with nests often 0.75 - 1 km apart. An analysis of potential breeding habitat characteristics of *rufa* developed from locations of 21 nests on Southampton Island and relocations of radio-tagged birds over a wider section of the central Arctic (see Figure 6) indicated knots were generally found at elevations of less than 150 m above sea level, less than 50 m from the coast, and in areas with less than 5% vegetation. Foraging habitats can be considerable distances (up to 10 km) from the nest, and are usually in damp or barren areas.

On migration and wintering areas, knots tend to favour coastal areas with extensive intertidal flats, usually sandflats (sometimes mudflats), where the birds feed on bivalves and other benthic invertebrates. On the wintering grounds, major habitats are the massive intertidal sandflats and mudflats at Bahia Lomas, Chile (also Bahia San Sebastian, Argentina) in Tierra del Fuego. At Rio Grande on the Atlantic coast of Tierra del Fuego, Argentina, and on migration areas on the coast of Patagonia, knots also forage on *restinga* habitats consisting of rocky intertidal platforms that support a variety of invertebrates. During spring migration in Delaware Bay, knots forage on sandy beaches used by nesting horseshoe crabs (*Limulus polyphemus*), feeding on the eggs of the crabs. They may on occasion also forage on tide wrack on beaches. In addition to sandy beaches, knots use peat banks (mussel spat), salt marshes, brackish lagoons, mangrove areas, and mudflats on migration (and in winter) in southeast USA and in Brazil (Niles et al. 2005).

An important aspect of habitat quality for knots is the proximity of suitable roosting areas that provide an undisturbed area safe from ground or aerial predators.

Habitat trends

It is unlikely that any major changes in the extent of breeding habitat have occurred in the Arctic, though long term changes resulting from climate change are likely to affect

knots, probably in a negative fashion (Meltofte et al. 2005). Knot habitats used on migration are thought to have decreased considerably on both the east and west coasts of North America (see Trends section for a fuller discussion). Habitats in South American locations are generally less disturbed, though they face a variety of potential environmental concerns and threats (see Threats section).

Habitat protection/ownership

Some of the more important Red Knot habitats have been recognized by various conservation and habitat protection programs and initiatives, providing a variable amount of formal and informal protection (Table 2). These programs include: (1) the Western Hemisphere Shorebird Reserve Network, a non-government organization that identifies and seeks protection for important shorebird sites; (2) the Ramsar Convention, a world wide intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands; (3) the Important Bird Areas (IBA) program of BirdLife International, which identifies and promotes conservation of important areas for birds; and (4) various other designations, often at a national, state, or regional level. These initiatives raise the profile of important areas, and may provide some level of legal protection for key habitats.

Table 2. Recognition/status of key sites used by Red Knots by conservation organizations, including the Western Hemisphere Shorebird Reserve Network (WHSRN), the Ramsar Convention (Ramsar), the Important Bird Areas initiative of BirdLife International (IBA), and other designations. "x" indicates the site has been officially recognized by the organization.

Site	WHSRN	Ramsar	IBA	Other ¹
Bahia Lomas, Argentina		x		
Rio Grande/Bahia San Sebastian	x	x	x	x
Peninsula Valdes, Argentina			x	x
San Antonio Oeste, Argentina	x		x	x
Lagoa do Peixe, Brazil	x	x		x
Maranhão, Brazil	x	x		
Delaware Bay, USA	x	x ²		x
James Bay, Canada		x ³		x
San Francisco Bay CA	x			
Grays Harbor estuary WA	x			
Fraser River estuary in BC	x			
Guerrero Negro - Mexico				x
Bahia de Santa Maria - Mexico	x			

¹ e.g., State or Provincial reserves, wildlife reserves; ² Delaware estuary; ³ Southern James Bay

BIOLOGY

The information in this section is drawn mostly from material in the species account in *Birds of North America* (Harrington (2001) and in the US Red Knot status assessment *Status of the Red Knot (Calidris canutus rufa) in the Western Hemisphere* (Niles et al. 2005).

Life cycle and reproduction

Breeding

Red Knots have a monogamous mating system. Egg laying occurs after a period of physiological reorganization, with eggs being formed from local food resources rather than from body stores brought from migration areas (Morrison and Hobson 2004). Pair bonds form soon after arrival and remain intact until shortly after the eggs hatch. Knots generally start breeding at age two. Mating occurs on the breeding grounds. Clutches consists of four eggs, occasionally three. Only one clutch is normally laid per year. Nests are simple scrapes usually placed in small patches of vegetation, and may contain lichens and other pieces of vegetation as lining. Incubation takes 22 days and is shared by males and females. Territories are large (and hence nest densities are low), with nests widely separated (typically 0.75 - 1 km apart). Although territories are defended from other conspecifics, off-duty birds tend to feed away from their territory in communal feeding areas. Knots often return to the same general breeding area from year to year, though little is known concerning the details of site or mate fidelity. The female departs a few days after hatch, leaving the male to care for the brood; fledging takes approximately 18 days. Hatching occurs in the first half of July. The young leave the nest within 24 hours, and as soon as they are mobile (within a day or two) the brood wanders over large distances (several kilometers or more) across the tundra. Following fledging, the males depart, being followed by the juveniles one to three weeks later. Nesting success may vary considerably from year to year, depending on weather conditions and predator cycles.

Migration and wintering

During the non-breeding seasons, knots gather in large flocks on migration and wintering areas, feeding in coastal intertidal areas and roosting on nearby beaches, marshes or fields, where open undisturbed habitat is available. Not all juveniles reach the most southerly parts of the wintering range (Baker et al. 2004, 2005b). Second year immatures are found on the major wintering areas, and move north to breed when two years old.

Longevity and survival

The oldest Red Knot recorded (*C. c. islandica*) was originally banded on The Wash, SE England, in August 1968 as an adult and recaptured there in September 1992 (Wash Wader Ringing Group 2005). Since it could not have hatched later than July 1967, it

was at least 25 years old when recaptured. One *islandica* knot bred near Alert, on the north coast of Ellesmere Island, over a period of at least 11 years between 1992 and 2002 (R.I.G. Morrison unpublished data). The oldest recorded *rufa* knot was originally banded as a juvenile at Punta Rasa, Argentina, in October 1987 and recaptured on the wintering grounds at Bahía Lomas, Tierra del Fuego, in February 2003, making it 16 years old (Niles et al. unpublished data). Although these records demonstrate that the potential lifespan of a Red Knot is considerable, most live much shorter lives. Annual adult survival in stable populations has been estimated at around 80% and the survival of juveniles is about half that (Boyd and Piersma 2001). Very few knots therefore live for more than about 7 - 8 years.

Predation

On the breeding grounds in the Canadian Arctic, major predators of nests/eggs include Arctic foxes (*Vulpes lagopus*) and Long-tailed Jaegers (*Stercorarius longicaudus*), and sometimes Arctic wolves (*Canis lupus arctos*); these species, as well as other species of jaegers (Parasitic Jaeger *Stercorarius parasiticus*, Pomarine Jaeger *Stercorarius pomarinus*), gulls (Herring Gull *Larus argentatus* and Glaucous Gull *Larus hyperboreus*), falcons (Gyr Falcon *Falco rusticolus* and Peregrine Falcon *Falco peregrinus*), and owls (Snowy Owl *Bubo scandiaca*), may take chicks and sometimes adult birds. Predation pressure may vary considerably in different years depending on the abundance of lemmings: in years of high lemming abundance, most of the above predators focus on lemmings as their major prey, whereas in years of low lemming abundance, predators are forced to turn to alternative prey, including shorebirds.

On migration and wintering areas, the most common predators of Red Knots are large falcons, such as the Peregrine Falcon, harriers, accipiters, smaller falcons such as Merlin (*Falco columbarius*), owls (Short-eared Owl *Asio flammeus*), and large gulls (Great Black-backed Gull *Larus marinus*). Butler et al. (2003) and Ydenberg et al. (2004) have pointed out that the increase of raptor populations over the past several decades has affected the behaviour of small shorebirds, and it is possible that knots are also being affected. For instance, it appears that falcons have influenced shorebird distribution between and within the upper arms of the Bay of Fundy (NSDNR 2004). In addition to increasing the risk of direct predation, the presence of aerial predators has the potential to affect energy budgets of the birds through disturbance and forced additional flight. No information is available on whether raptor predation is a significant pressure on the wintering areas.

Physiology

During the final stopover on northward migration, knots undergo a host of physiological changes (Piersma et al. 1999; Baker et al. 2004). For example during the middle of the stopover period, their digestive organs tend to increase in size, at a time when they are rapidly laying down fat. Towards the end of their stay, the fat deposition continues, while at the same time the “exercise organs” (or “flight machinery” - heart, flight muscles, fat) that will power the flight increase in size; in contrast, the “digestive organs”

and muscles that will be used less or not at all during the flight (the “baggage” - leg muscles, gizzard, gut, liver) actually decrease in size, so that by the time the bird departs, it is exquisitely adapted for the long flight to the Arctic. Knots arrive on the breeding grounds with stores of fat and protein still remaining. These fat and protein stores are lost at the same time that gut, gizzard, heart (which decreased in size during flight), liver, gonads, etc. are regrown in preparation for the breeding attempt (Morrison et al. 2005). Failure to accumulate the needed stores and to undergo the series of physiological transformations before migration and before breeding appear to have severe survival consequences (Baker et al. 2004; Morrison 2005; see Threats section).

Dispersal/migration

Rufa undertakes one of the longest migrations of all the knot subspecies, moving from breeding grounds in the central Canadian Arctic to wintering grounds at the southern tip of South America (Morrison 1984). The southern “wintering” areas in Tierra del Fuego and Patagonia are occupied from approximately October to February. Knots are found on migration at the Valdes Peninsula and at San Antonio Oeste on the Patagonian coast of Argentina during March and April, before moving on to Lagoa do Peixe in southern Brazil, where they occur from late March through April. By late April or early May the birds move northwards through Maranhão on the north-central coast of Brazil, and then fly to the eastern seaboard of the USA, where they pass up the coast of the Carolinas, Virginia, and Maryland, and into Delaware Bay. *Rufa* refuel in Delaware Bay in May, departing from the last week of May to early June. Small numbers are found migrating through areas such as Point Pelee National Park and Presqu’île Provincial Park on the Canadian Great Lakes from around mid May to early June (McRae 1982; Weir 1989; Morrison and Harrington 1992; V. MacKay pers. comm.). They are observed passing northwards through the southern part of James Bay in the last days of May or early June, and arrive on the breeding grounds in early June (Morrison and Harrington 1992).

The return migration begins in the latter half of July, with adult birds passing through James Bay, the north shore of the St. Lawrence River, and the Maritime Provinces in late July or early August (see references in caption for Figure 7). Passage through the New England coast and areas farther south on the Atlantic coast of the USA is somewhat later. Juveniles migrate southwards in August, passing through the east coast of Canada from mid August to around mid September. Passage through Suriname (Spaans 1978) is in the second half of August and first half of September for adults, a second peak in October probably referring to juveniles. The birds may move farther east along the north coast of South America, before flying across Amazonia, passing through the Atlantic coast of southern Brazil, Uruguay, and northern Argentina from September onwards. Passage down the coast of Argentina occurs during October, with arrivals on the southern wintering area in that month (Baker et al. 2005b).

Most of the *rufa* occurring in Tierra del Fuego are adults; juveniles made up 6% of the population in 2004 (Baker et al. 2005b). Many juveniles are thought to remain in southern areas during their first northern summer, perhaps moving some way towards

the breeding grounds, but not completing the full migration (e.g., Belton 1984). Birds in their second year (immatures) are found in Tierra del Fuego; percentages in flocks fell from 19% in 1995 to 10-13% in 2001-2004 (Baker et al. 2005b).

Knots concentrate to a remarkable degree at favoured sites during the winter and on migration. In recent years, 97 - 98% of *rufa* knots on the wintering areas occurred in Tierra del Fuego, with about 83% of the population at one site, Bahia Lomas (Morrison et al. 2004, unpublished data). On migration, Gonzalez et al. (1996) estimated that at least 20% of the population passed through San Antonio Oeste (based on a high total population estimate of 125,000 knots: the figure was likely closer to half this, indicating about 40% of the population used this site). In Delaware Bay, Atkinson (2005) recently estimated that about 50% of *rufa* pass through that area in spring.

Knots appear highly site faithful in all parts of their range. On the wintering grounds, Baker et al. (2005b) reported many recaptures of birds previously banded at Rio Grande at the same place, and many resightings and recaptures of the same (colour marked) individuals have been made at San Antonio Oeste and Delaware Bay (P. Gonzalez, R.I.G. Morrison, A.J. Baker, L.J. Niles unpubl. data). At Alert, many *islandica* return to the same breeding area from year to year (Morrison et al. 2005, unpublished data), and studies on Southampton Island in 2000-2004 indicate that the same occurs with *rufa* (Niles et al. 2005).

Interspecific interactions

Red Knots appear dependent on the eggs of the horseshoe crab as their main prey in Delaware Bay and other coastal areas of the USA during spring migration.

Adaptability

Given the high site fidelity of knots on their wintering, migration, and breeding areas, it is difficult to predict whether they would adapt readily to new or different areas under changing environmental conditions, even if such areas were available. The fact that knots have declined rapidly in the face of decreasing food resources in Delaware Bay suggests that they have not successfully been able to find alternative foods or foraging areas to meet their requirements on northward migration. Knots show many specializations in life history and physiology (Piersma and Baker 2000; and see Physiology section), and their traits of low fecundity (clutch size ≤ 4 eggs, high nest failure, only one brood per year), delayed maturity, and high annual survival (70 - 90%) (Sandercock 2003) would appear to make them vulnerable to rapid environmental change. Knots have very low genetic variability and it is not known if this may imply reduced behavioural plasticity and a greater susceptibility to environmental perturbations (Baker et al. 1994; Piersma and Baker 2000).

POPULATION SIZES AND TRENDS

Search effort

Wintering grounds

Counts on the wintering grounds are considered the best method of assessing population size, since the birds are resident and little movement is likely to occur between sites; it is the method of choice recommended for the species in technical documents accompanying the US Shorebird Conservation Plan (Brown et al. 2001). Coverage of the entire wintering range in effect enables a census to be carried out, in which all of the birds are counted. Uncertainties in the total are related to counting and detection errors, since there is no sampling or extrapolation involved. Following surveys in the 1980s, counts on the major wintering areas were resumed in 2000 and have continued through 2006. The entire wintering range in Patagonia and Tierra del Fuego has been covered in three of those years in order not only to count all birds, but also to determine whether any changes at the principal sites may have been caused by redistribution within the range.

A major feature of the South American wintering surveys is that they have all been carried out by the same observers, Morrison and Ross, thus eliminating concerns that changes in numbers may be caused by an observer effect.

Counts from Tierra del Fuego and estimates of the population made through re-sighting studies conducted during migration have been in close agreement (Gonzalez et al. 2004). Ground and aerial counts conducted at Bahia Lomas, Chile and at Rio Grande, Argentina have also agreed closely (RIGM, RKR, and LJN unpublished data).

Migration

Although counts at migration areas may be affected by turnover (birds moving through the site at different times, or at different rates in different years) and uncertainties regarding the proportion of the population using the site (Bart et al. 2005), they can nevertheless provide valuable additional data on trends in a migratory population (Morrison et al. 1994; Morrison 2001). Maximum counts or mean counts (sometimes during a specific time window, e.g., to estimate adult numbers, where their passage time differs from juveniles) have been used as indices of annual abundance. Trends in *rufa* populations have been estimated from counts at various locations in both South and North America; trend estimates from migration areas in southern South America have the advantage that they involve only *rufa* knots.

South America

San Antonio Oeste, Rio Negro Province, on the coast of Patagonia in Argentina, is a major stopover area for *rufa* knots during northward migration. A complete "local census" is conducted by experienced observers approximately weekly during March and

April, covering all the beaches used by knots and thus providing a comprehensive count of birds in the area. Data are available for the 16 year period 1990 – 2005. Counts have been conducted at Fracasso Beach, on the Valdes Peninsula, Chubut Province, Patagonia, Argentina, between 1994 and 2005 at regular intervals during the passage period in March and April. Finally, a series of counts spanning the years 1995 to 2003 is available from the National Park at Lagoa do Peixe, Rio Grande do Sul state, in southern Brazil, another major stopover area for *rufa* knots.

Delaware Bay

The most comprehensive data on knots during northward migration in the USA comes from Delaware Bay, the critically important final stopover area before the birds take off for their breeding areas. Aerial surveys have been conducted since 1982, and a standard survey procedure was adopted in 1986 involving weekly flights (6) during the period early May to mid June over areas used by knots in New Jersey and Delaware (Clarke et al. 1993, 2001). The same observers have taken part in all flights. *Rufa* knots may mix with the Florida/SE US and Maranhão, Brazil populations of *C. c. roselaari* during migration through the bay. However, knots from the latter two groups generally pass through this site somewhat earlier than *rufa* (Atkinson et al. 2005).

Eastern North America

In Canada, information on knot trends has come from the Maritimes Shorebird Survey (MSS) scheme, a survey program in which volunteers collect data on shorebirds in a consistent manner at their study site at two-weekly intervals throughout the period of southward migration (Morrison et al. 1994; Morrison 2001; Morrison and Hicklin 2001). The scheme has operated for over 30 years (1974 – ongoing), and a number of sites have had coverage by the same observers throughout that period. The MSS, along with the International Shorebird Survey (ISS) program collecting similar data in the USA (Howe et al. 1989), is the longest running shorebird survey program in North America. In Quebec, knot trends have been obtained from analysis of checklist data submitted to the Étude des populations d'oiseaux du Québec (ÉPOQ) for areas along the St. Lawrence River system between 1976 and 1998 (Aubry and Cotter 2001a,b).

Breeding grounds

The only information on recent trends in knot numbers on the breeding grounds in the central Canadian Arctic has come from studies conducted by Larry Niles on Southampton Island as part of the international Red Knot project. Surveys were conducted on a 9.2 km² study area annually between 2000 and 2005 (Niles et al. 2005).

Abundance

C. c. rufa.

Initial estimates of the size of the *rufa* population in the 1980s, derived from band re-sighting data and counts, suggested the population numbered between 100,000 and 150,000 (B. A. Harrington unpubl. results in Morrison and Harrington 1992). This estimate included *rufa* wintering in southern South America, as well as the Florida/SE US and Maranhão, Brazil populations (Harrington et al. 1988; Morrison and Harrington 1992; Morrison et al. 2001a). During this period, Morrison and Ross (1989) reported aerial survey totals for South America of 76,400 overall, with 67,500 of this total being *rufa* and the remaining birds part of the Maranhão, Brazil population.

By the latter part of the 1990s, the population counts from the southern wintering grounds of *rufa* were closer to 60,000 (Baker et al. 2001; Morrison et al. 2001b). The most recent population estimate for *rufa* derived from the wintering ground aerial census in 2005, suggests that this group may now number about 18,000 - 20,000 individuals, of which 75% or 13,500 -15,000 are adult birds (Table 3). Estimates of the population size from band re-sighting data during this period were consistent with the aerial counts (Gonzalez et al. 2004).

Losses on the wintering grounds were particularly evident at the “peripheral” sites along the coast of Patagonia compared to the major sites in Tierra del Fuego. In 1982/85 the Patagonian sites held 14,314 (21.2%) of the overall total, by 2002 this had fallen to just over 2,000 (6.9%), and was reduced further to less than 1,000 in 2003 and 2004 (1.8% and 2.8%, respectively; Morrison et al. 2004).

C. c. roselaari.

An aerial survey of the Maranhão coast of north-central Brazil in 2005 produced a total of 7,600 knots of which 5,700 are mature adults (Table 3; Baker et al. 2005a), similar to the 1982/85 total of 8,150 (Morrison and Ross 1989). Estimates for the Florida/SE US population over the past 20 years have ranged between 10,000 (Morrison and Harrington 1992), 7,500 (B.A. Harrington pers. comm. 2005), and 4,500 (Sprandel et al. 1997; Niles et al. 2005). The most recent estimate based on aerial and ground surveys during the winter of 2005-2006 is 4,500, of which 3,375 are mature individuals (Table 3; LJJ unpublished data). Finally, the Pacific coast population numbered 6,000 – 9,000 in 1981. The current total for the entire Pacific coast is 2,000 - 4,000, of which 1,500 – 3,000 are mature (Table 3; R.I.G. Morrison unpubl. data; G. Page and D. Paulson pers. comm. 2005). The current overall population estimate for *C. c. roselaari* involving the populations wintering on the Pacific coast, in Florida, and in Maranhão is 17,100 individuals of which 12,825 are mature individuals (Table 3).

C. c. islandica.

The current estimate for *C. c. islandica* is approximately 270,000, of which 202,500 are mature, based on midwinter counts in the United Kingdom and The Netherlands of

250,000, plus a further 20,000 in France (Table 3; T. Piersma pers. comm.); this estimate is somewhat lower than recent estimates by Wetlands International (2005a,b), though similar to the estimate produced in 2003 using the TRIM (Trend analysis and Indices for Monitoring data) method (Wetlands International 2005b). Canada is thought to hold about 81,000 or 40% of the breeding population of *islandica* (Morrison et al. 2007).

Table 3. Current population estimates of the three subspecies of the Red Knot that occur in Canada. (Bracketed numbers indicate uncertainties and possible overestimates – see footnotes.)

Subspecies	Estimated population size	Source
<i>islandica</i>	270,000 (202,500 mature; 81,000 breed in Canada)	T. Piersma, pers. comm. Morrison et al. 2007
<i>roselaari</i>	17,100 ¹ (12,825 mature)	present estimates, involves separate biogeographical populations wintering in Florida/SE US (4,500 – counts from surveys in winter 2005-2006, LJN pers. comm.), Maranhão, north-central Brazil (7,600 – Baker et al. 2005b), Pacific coast ² (2,000 - 4,000 – G. Page and D. Paulson pers. comm. 2005), and other areas (1,000 - see note 1)
<i>rufa</i> Tierra del Fuego & Patagonia	18,000 - 20,000 ³ (13,500 -15,000 mature)	Morrison et al. (2004, and unpublished data)

¹ *Roselaari* appears to have a much smaller population than that previously suggested (35,000-50,000) by Wetlands International (2005). The Wetlands International estimate included birds wintering from Florida through the Caribbean to N South America, which were considered to belong to this subspecies, as well as the Pacific coast. This total was based on previous estimates some of which now appear to be too high: previous totals for Florida (7,500 B.A. Harrington pers. comm. 2005), Texas (3,000 B.A. Harrington pers. comm. 2005), Pacific 6,000-9,000 (Page et al. 1999), North-central Brazil (8,200 Morrison and Ross 1989) and birds wintering in northern Venezuela (520, Morrison and Ross 1989) and Panama (200, Buehler 2002), come to approximately 28,400. Current estimates are closer to 17,100 and would include distinct biogeographic populations in Florida (4,500), Maranhão (7,600), Pacific coast (2,000-4,000) and miscellaneous other areas (Texas 300 (Skagen et al. 1999), northern Venezuela 520 (Morrison and Ross 1989), and Panama 200 (Buehler 2002)). Knots are also known to occur on some Caribbean islands (e.g., Cuba) during the winter; there is little information available, but numbers are not thought to be large.

² Previous estimate of 9,000 is likely an overestimate as it was based on counts summed across seasons (Page et al. 1999, G. Page pers. comm.): previous counts have included 6,000 migrating northwards through the Pacific Northwest USA, but there have been no recent reports of such large numbers. Winter counts suggest the total may be closer to 2,000-4,000 for the entire Pacific coast (R.I.G. Morrison unpubl. data; G. Page and D. Paulson pers. comm. 2005), an estimate compatible with observations of 2,000 - 3,000 knots on southward migration in the Pacific Northwest USA in 2006 (J. Buchanan pers. comm.).

³ The estimate for *rufa* in Wetlands International (2002) would include the approximately 18,000 in Tierra del Fuego/Patagonia and the approximately 7,600 on the north-central coast of Brazil. Note that these are considered separate biogeographic populations and that the birds in Brazil are presently included in the *roselaari* group.

Fluctuations and trends

C. c. rufa

Wintering grounds

The best trend information for *rufa* knots come from surveys conducted on the wintering range, where there is no mixing with other populations. Overall, the wintering population of *C. c. rufa* has decreased from approximately 67,500 birds in 1982 (Morrison and Ross 1989) to approximately 18,000 in 2006, a decrease of 73.4% in the last 24 years. The rate at which this decline has occurred differs between the core and peripheral wintering areas and over the above time period (Figure 8). That is, the rate of decline was relatively slow between 1982 and 2000, particularly at the core sites, and then increased dramatically between 2000 and 2006 (Figures 8 and 9).

Specifically, the annual rate of decline over all wintering sites between 1982 and 2000 was -1.2%. The rate, however, increased to -17.0%/year between 2000 and 2006 at the core sites, where most of the population now resides (Figure 9). Assuming a linear decline in population size between 1982 and 2000 (see Figure 8), the estimated *rufa* population in 1991 (i.e. 15 years or approximately 3 generations ago) would have been approximately 60,900 individuals. This means the population would have decreased by 70.5% in the last 15 years or 3 generations, given the current population size of 18,000 birds.

Migration trends

Although migration counts are not independent of the counts on the wintering grounds (i.e. they include the same birds), they do show a highly consistent pattern to those described above. In turn, this suggests that declines have not been caused by redistribution of birds on the wintering grounds, but rather reflect a true population decrease. Indeed, no redistribution of birds was found on aerial surveys across the southern wintering areas (Morrison et al. 2004).

South America

Survey data from stopover areas used as the birds move to their wintering grounds in South America (i.e. two on the coast of Patagonia, Argentina and one in southern Brazil) show similar trends to those described above for the wintering grounds in Tierra del Fuego. For instance, *rufa* knots passing through the Valdes Peninsula, Argentina showed a significant annual rate of decline of -22.4% between 1994 and 2005 ($r = 0.725$, $R^2 = 0.526$, $p < 0.017$). If the rate of decline for this 11 year period is extrapolated to cover a 15 year period, the population at this site would have decreased by 97.8% in the last 3 generations. Similarly, birds at the second stopover site in Argentina, San Antonio Oeste, showed a significant annual rate of decline of -8.0% between 1990 and 2005 ($R^2 = 0.717$, $p = 0.003$). At this rate of decline, the population at this site would have decreased by 71.5% over the last 15 years. Finally, *rufa* passing

through the third site in southern Brazil, showed a significant annual rate of decline of – 30.6% between 1995 and 2003 ($r = 0.928$, $R^2 = 0.862$, $p < 0.0009$). Again, if this rate of decline is applied over a 15 year period, the population at this site would have decreased by 99.6% in the last three generations.

In summary, migration counts at three sites in South America also showed strong declines in the last 8 to 15 years, with annual rates of decline ranging from -8.0% to - 30.6%. At these rates, the populations at the above sites would have decreased between 71.5% and 99.6% over the last three generations.

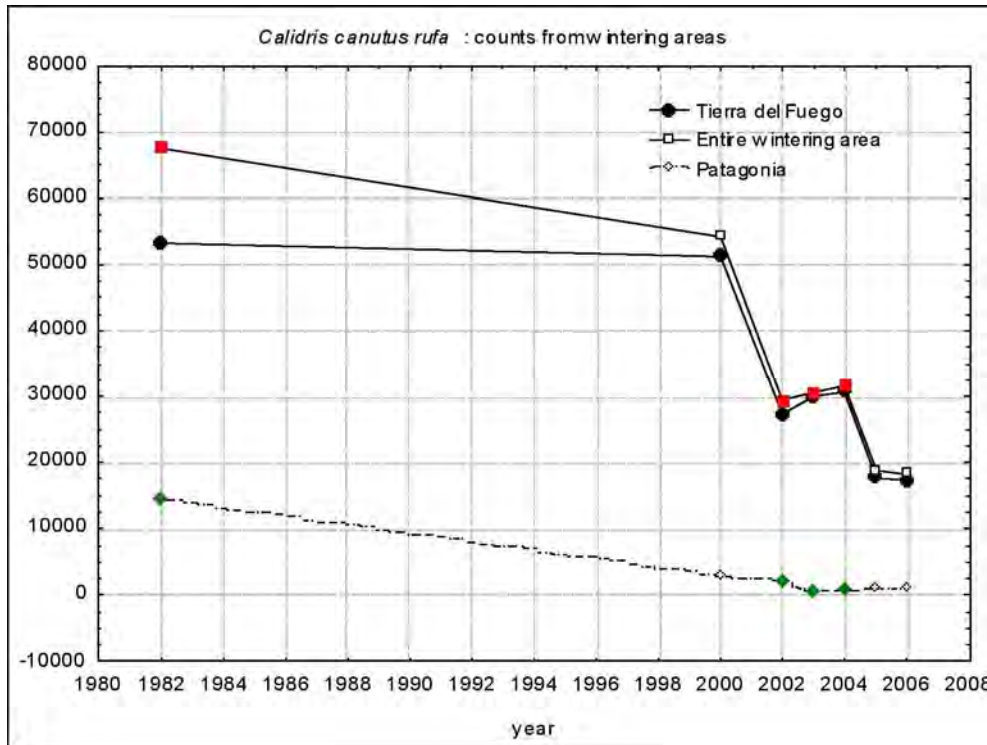


Figure 8. Population estimates of Red Knots *rufa* subspecies in southern South America from aerial surveys conducted in 1982/1985 and 2000 – 2006. Solid symbols: counts from aerial surveys; open symbols, estimated totals (value for Patagonian sites in 2000 from regression equation, values for Patagonian sites in 2005 and 2006 taken as average of counts for Patagonian sites in 2002-2004). Upper line (squares) – overall wintering population; middle line (circles) – major wintering sites in Tierra del Fuego; lower line (diamonds) – “peripheral” sites in Patagonia.

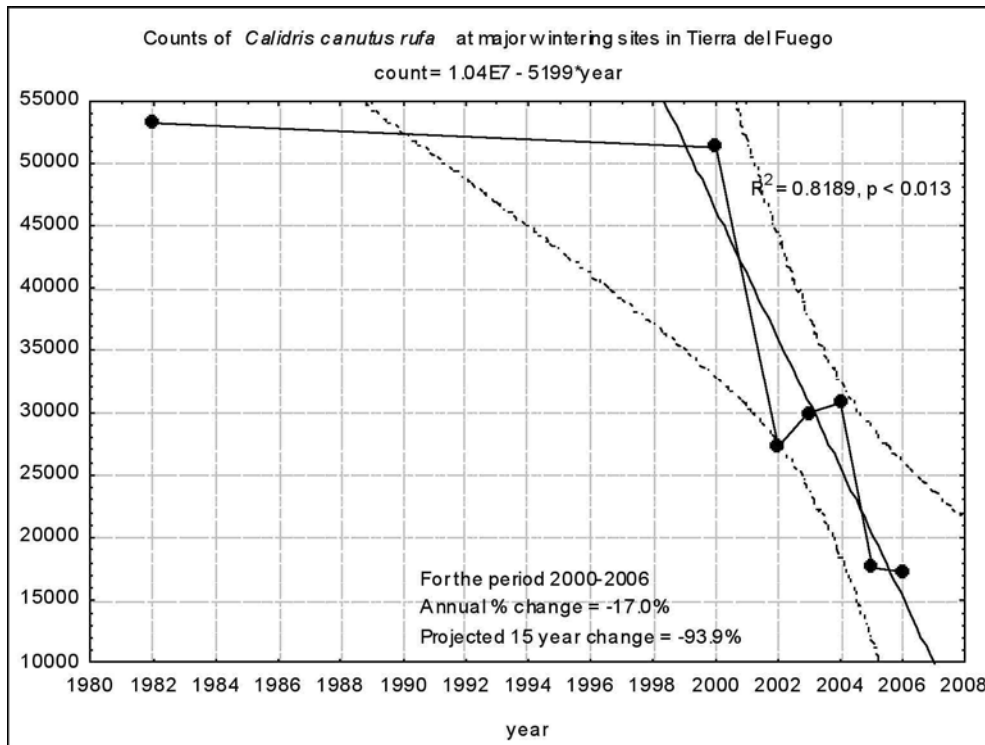


Figure 9. Counts of *C. c. rufa* at major wintering sites in Tierra del Fuego. Data suggest little change from 1982 to 2000, followed by rapid declines.

Delaware Bay

Delaware Bay on the east coast of the USA is the key final refueling stop for *C. c. rufa* wintering in South America before the final leg of their journey to the Arctic breeding grounds. Knots from the Florida/SE and Maranhão Brazil populations of *C. c. roselaari* (see below for wintering ground trends) also pass through this site, though probably slightly earlier than the *rufa* knots (Atkinson et al. 2005). Survey data from this site show a significant annual rate of decline of -4.4% between 1982 and 2006 ($R^2 = 0.283$, $p = 0.009$), with a peak of 95,000 in 1982 to less than 15,000 in 2006.

Surveys between 1992 and 2006 show a significant annual rate of decline of -5.85% (Figure 10). At this rate of decline, the population would have decreased by 59.5% over the last 15 years (three generations).

The prolonged decline in counts in Delaware Bay appears to reflect the declines in the *rufa* population wintering in Tierra del Fuego, possibly accelerating declines in the Florida population, and the suspected declines in the Maranhão population.

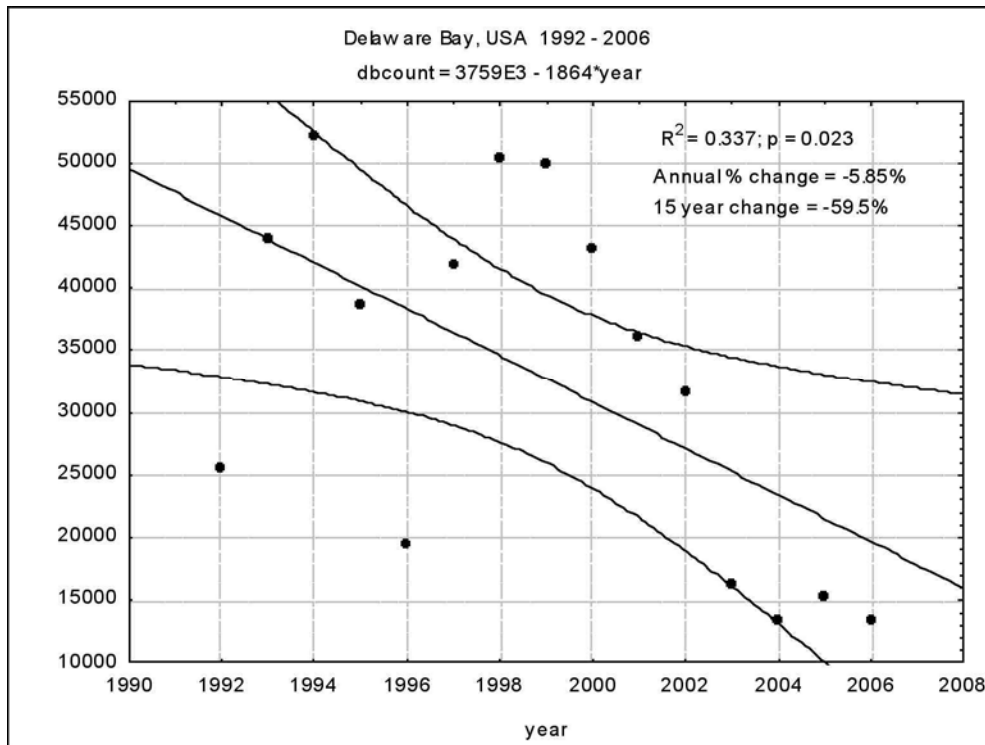


Figure 10. Maximum counts observed during aerial surveys of Red Knots during northward migration in Delaware Bay, 1992-2006. Adapted from Niles et al. (2005) and R. I. G. Morrison and R. K. Ross (unpublished data). Knots from separate biogeographic populations wintering in Tierra del Fuego, Maranhão, and Florida pass through Delaware Bay.

Eastern North America

Combined data from the International (east coast USA) and Maritimes (Atlantic Canada) shorebird survey schemes collected during fall migration have shown a significant long-term annual rate of decline of -13.3% between 1972 and 1998 (more recent data are not available; Figure 11). Like Delaware Bay, these trends reflect changes in populations of *rufa* and the Florida/SE US and Maranhão, Brazil populations of *roseaari* (see below).

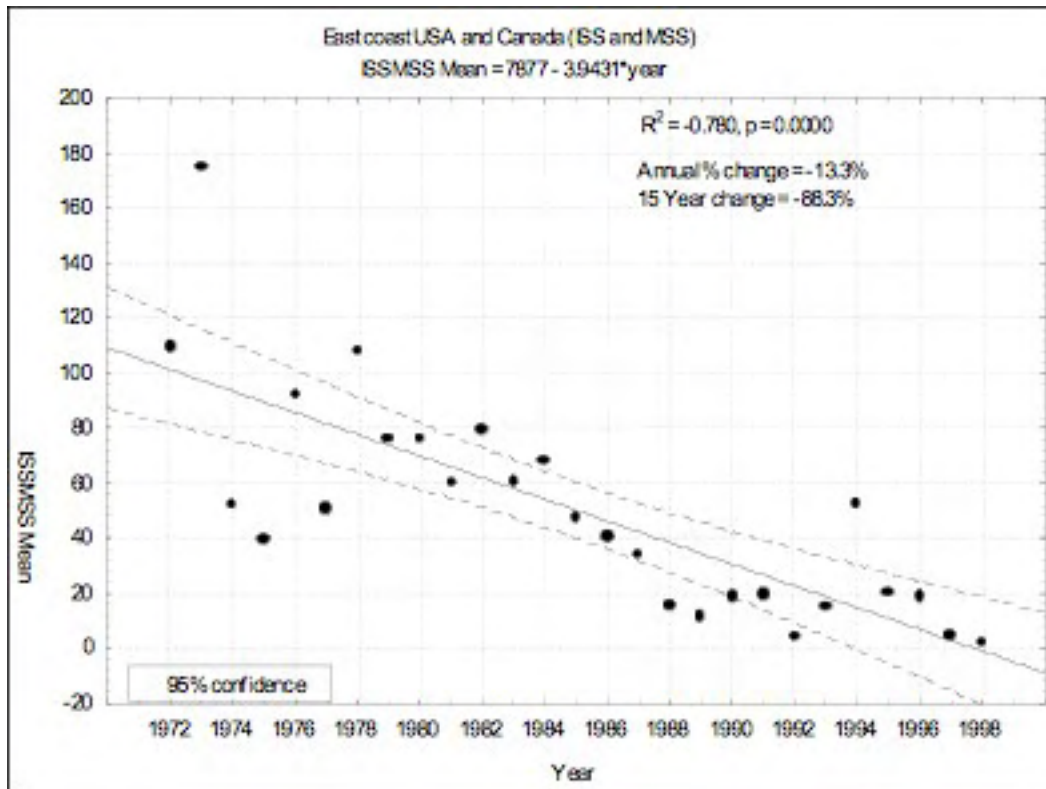


Figure 11. Mean counts of Red Knots observed during southward migration on the east coasts of the USA and Canada (from International Shorebird Survey and Maritimes (Atlantic Canada) Shorebird Survey datasets), 1972-1998. (B.A. Harrington unpublished data; R.I.G. Morrison, unpublished data). Counts likely include knots from separate biogeographic populations wintering in Tierra del Fuego, Maranhão, and Florida.

Breeding grounds

The only information available on trends from *rufa*'s central Canadian Arctic breeding grounds was obtained by L.J. Niles from Southampton Island, where a 9.2 km² study area was censused between 2000 and 2004. Breeding densities of knots fell from 1.16 nests/km² in 2000 to 0.33 - 0.55 nests/km² in 2003 - 2004. The difference in mean density over the first three years compared to the last two years was significant (ANOVA, $F_{1,3} = 10.09, p = 0.0502$).

Population modeling and possibility of extinction.

Demographic studies by Baker et al. (2004) showed that survival of the Tierra del Fuego adults declined from an average of 85% in 1994 - 1998 to only 56% during 1999 - 2001. Population projections were developed using a matrix model under two scenarios (Figure 12): (a) The "best case scenario", in which adult survival returned to 85%, juvenile survival was assumed to be half that of adults, and fecundity averaged 0.29; and (b) a "worst case scenario" in which adult survival remained at 56%, with juvenile survival half that of adults and a mean fecundity of 0.29. Under the best case scenario,

the Tierra del Fuego population (including immature birds wintering farther north) would remain stable at about 70,000 birds, based on the 2000 count data from South America (Morrison et al. 2004). However, if the worst case scenario prevailed, with seriously depressed levels of adult survival, the population would fall rapidly to very low levels by 2010, putting it at immediate risk of extinction. Between 2000 and 2002, the model predictions using the adult survival of 56% closely followed the field data. Between 2002 and 2004, the population apparently stabilized somewhat in the 27,000 – 31,000 range, but the dramatic drop to only 17,650 in 2005 and 17,211 in 2006 brought it back close to the track of the worst case scenario once again, suggesting a trajectory heading once more towards extinction. Atkinson (2005) analysed band returns in Delaware Bay and suggested that survival of the southern wintering population may have recovered somewhat in 2002 - 2004, when the population stabilized on the wintering grounds. It is clear, however, that increased mortality and/or lack of recruitment seriously impacted the population again in 2005, and that problems for the *rufa* knot population are ongoing.

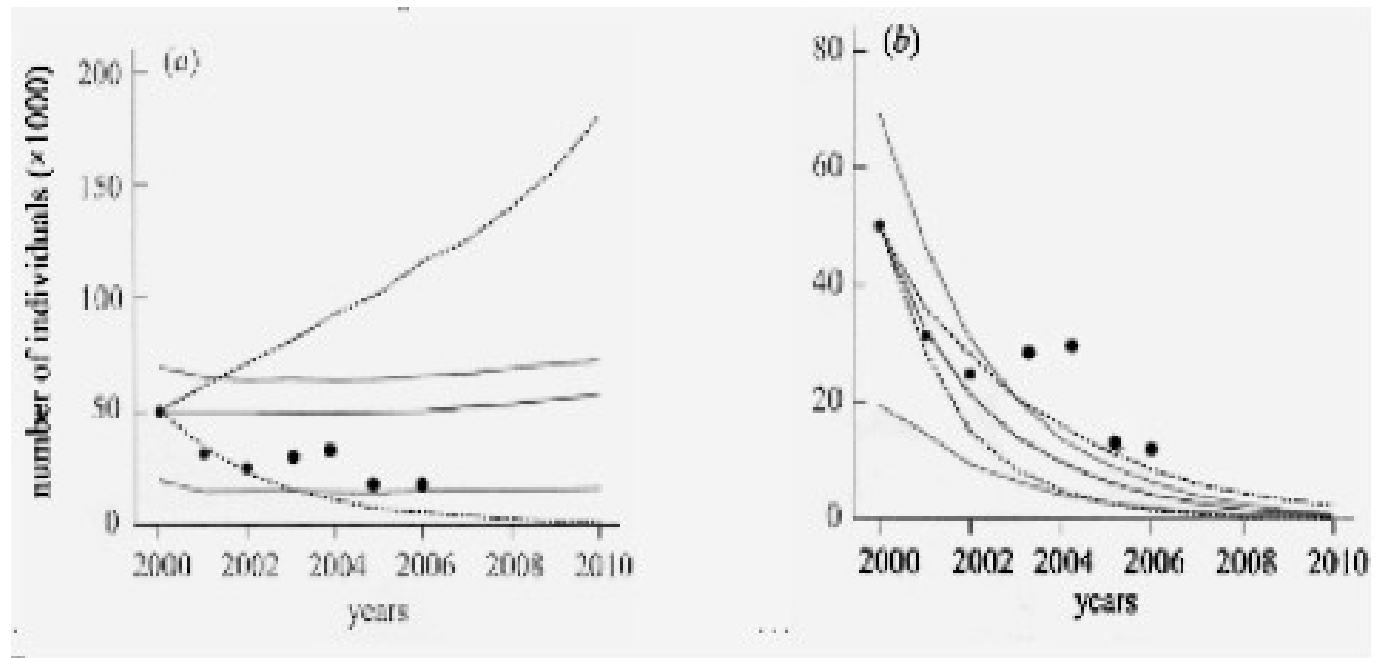


Figure 12. Predicted population trends of adult *rufa* Red Knots (middle grey line), juveniles (lower gray line), and the sum of these two age groups (top gray line) for 10 years from 2000; associated 95% confidence limits for adults are shown as dashed lines. Two scenarios are presented: (a) constant adult survival of 85%, with juvenile survival being half that of adults ($\lambda = 1$); and (b) constant adult survival of 56%, with juvenile survival being half that of adults ($\lambda = 0.66$). The dots represent aerial census counts of over-wintering knots in Tierra del Fuego during 2000 - 2006 (Morrison et al. 2004, and unpubl. data). The 95% upper and lower confidence limits are based on 1,000 bootstrap iterations. Modified from Baker et al. (2004, and see Baker et al. 2005a).

C. c. roselaari

Wintering grounds

The best trend information for *C. c. roselaari* also comes from counts on the wintering grounds.

Florida/SE US population: The portion of the population wintering in Florida has dropped from 10,000 up to the early 1990's (Harrington et al. 1988; Morrison and Harrington 1992) to 3,020 (2005 - 2006, LJJ pers. comm.). This represents a decrease of 70% over the last 15 years. The number of birds wintering outside Florida in the early 1990s is not known.

Little information is available from individual sites from which to derive trend estimates. The only site at which data are available from the early 1990s to the present (i.e., 15 years or 3 generations) is from Honeymoon Island, Florida (Niles et al. 2005). Here the population showed a significant annual rate of decline of -33.1% ($R^2 = 0.604$, $p = 0.002$). At this rate of decline, the population would have decreased by 98.1% over the last 15 years.

Maranhão, Brazil population: In the early 1980s, 8,150 knots were counted on the Maranhão coast on the north-central coast of Brazil (Morrison and Ross 1989). Aerial surveys of the same area were carried out by different observers in 2005, and resulted in a count of 7,600 birds (Baker et al. 2005a), a decrease of about 7% from the earlier survey. There is concern, however, that the most recent count may have involved some degree of overestimation, and it is likely that this population has also undergone a larger decline than the counts suggest (A.J. Baker unpubl. data.).

Pacific coast population: The most recent assessment of the overall population size of the Pacific coast population of *C. c. roselaari* is 2,000 – 4,000 birds based on counts of knots on wintering and migration areas (J. Buchanan pers. comm. 2006, Morrison et al. 2007). The population is thought to have declined from previous estimates of 6,000 – 9,000 birds in the 1990's (Paulson 1993; Page et al. 1999). This represents a decrease of approximately 60%, using the mid-point in the range of the counts. At Grays Harbor Washington, counts have declined from a high of some 6,000 knots recorded in 1981 (Paulson 1993) to only about 250 in 2006 (Buchanan 2006). Here the population showed a significant annual rate of decline of -12.0% ($R^2 = 0.92$, $p = 0.0002$). If this rate of decline were consistent over the most recent 15 year period, the population at this site would have decreased by 72.0% over the last 3 generations.

In summary, the Pacific coast and Florida/SE US populations of *C. c. roselaari* have shown a 60 to 70% decrease in population size, respectively, in the last 15 years. The Maranhão, Brazil population decline has been about 7% since the early 1980s, but a suspected overestimation in recent surveys indicates declines may be larger than indicated. Overall, the combined decline for the three populations is approximately 47% over the last 15-20 years based on a decline from a combined population of about

25,650 (10,000 + 8,150 + 7,500) in 1990 to about 13,620 currently (3,020 + 7,600 + 3,000). This number may, however, be conservative, if the Maranhão population was overestimated in recent surveys.

C. c. islandica

Wintering grounds

Estimated numbers of *C. c. islandica* wintering on the European seaboard have ranged between about 300,000 and 400,000 between the early 1970s and late 1990s. A series of poor breeding years in the 1970s led to declines, but the population recovered to a peak in the 1980s and has again fallen somewhat up to the late 1990s (Boyd and Piersma 2001; Collier et al. 2005; Wetlands International 2005b). Between 1998 and 2003, numbers wintering in the UK and Netherlands have fallen about 17% from about 300,000 to about 250,000 (Figure 13). The pattern over the last 15 years is presumably similar, given that the population was likely at the low end of the above range (i.e. 300,000) throughout the 1990's.

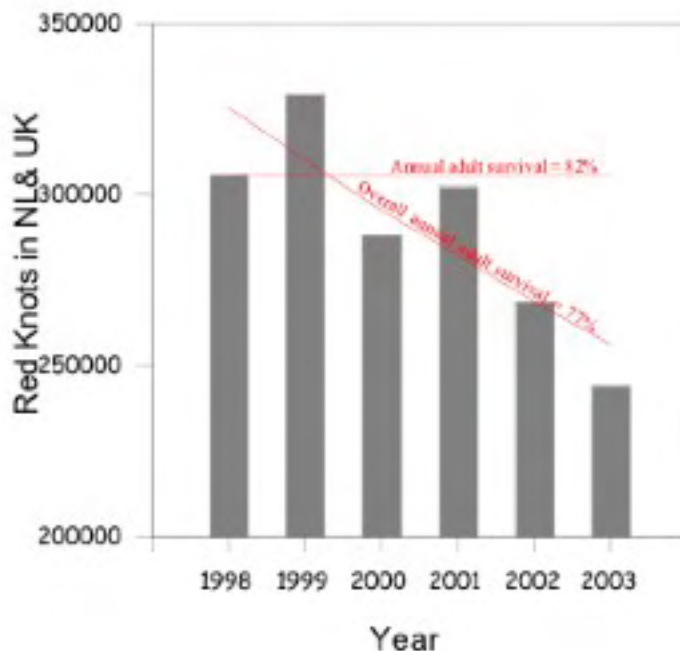


Figure 13. Declines of Red Knots subspecies *islandica* on wintering grounds in the United Kingdom and The Netherlands between 1998 and 2003 (T. Piersma pers. comm.).

Rescue effect

The present evidence, discussed elsewhere in this report, supports the view that *rufa*, *roselaari*, and *islandica* all form distinct biogeographic units with no detectable interchange. A rescue effect would not be anticipated for *rufa* and *roselaari*, whose

range is restricted to North America. There may be some rescue potential, however, for *islandica* from breeding populations in Greenland.

LIMITING FACTORS AND THREATS

Deterioration of food resources during spring migration

The principal known threat to knot populations (*rufa*, Florida/SE US and Maranhão, Brazil populations of *roselaari*) migrating northwards through eastern North America is the dwindling supply of horseshoe crab eggs at their final spring stopover in Delaware Bay; with *rufa* particularly at risk because of its much longer migration. Several studies have confirmed that horseshoe crab eggs are the major component of the diet of knots and other shorebirds during northward migration in Delaware Bay (Castro and Myers 1993; Botton et al. 1994; Tsipoura and Burger 1999; Haramis et al. 2002, 2005). This once superabundant food supply was literally decimated as a result of over-fishing of horseshoe crabs: mid-Atlantic state landings of horseshoe crabs rose from less than 1 million pounds before 1993 to a peak of over 6 million pounds in 1998 (falling to between 2 and 3 million pounds by 2002 - 2003; Morrison et al. 2004). As the number of breeding crabs decreased, egg densities in the upper 5 cm of sand on beaches in New Jersey fell from a mean of $33,373 \pm 18,906$ SD eggs m^{-2} in the period 1985 - 1991 to a mean of $3,026 \pm 1,675$ SD from 1996 - 2005 (ANOVA $F_{1,12} = 28.77$, $p = 0.0002$; Niles et al. 2005, data from Loveland and Botton (unpublished data) for 1985 - 1999, NJ Endangered and Nongame Species Program (unpublished data) for 2000 - 2005), a reduction of some 90%. Studies by Stillman et al. (2003) and Hernandez (2005) have shown that the latter densities are too low for efficient foraging by knots and that the birds may not be able to meet their energetic requirements during their stopover. The result is that the birds are unable to attain adequate departure masses before the flight to their Arctic breeding grounds, at least in some years (Baker et al. 2004). Failure to attain the required stores before migration can have severe fitness consequences.

Baker et al. (2004) showed that the proportion of knots reaching adequate departure masses in Delaware Bay decreased significantly by 70% during the period 1997 - 2002, and lower nutrient storage and possibly reduced sizes of intestine and liver during refueling led to severe consequences for adult survival and recruitment of young in 2000 - 2002. Adult survival fell from 85% during 1994 - 1998 to 56% in 1999-2001, and decreasing proportions of immature birds were found in flocks of knots in Tierra del Fuego between 1995 and 2001. Population modeling showed these factors predicted a population trajectory closely matching the observed declines of birds on the wintering grounds during the aerial censuses (Morrison et al. 2004), and furthermore predicted that if the survival was to remain at the reduced level (56%), the population was likely to be at risk of extinction as early as 2010 (Baker et al. 2004; see Fluctuations and trends above). Although the population appeared to stabilize from 2002 - 2004 on the wintering grounds, the large decrease in 2005 (confirmed in 2006) suggests the population is back near the "extinction trajectory". Other studies with shorebirds, including knots, have shown that birds in poorer condition during migration appear to

have lower survival rates (Pfister et al. 1998; Morrison 2005). These studies have provided an authoritative scientific basis for understanding the impact of reduced food supplies at the final stopover area.

Although protective measures have been introduced for knots in Delaware Bay, including cessation of the horseshoe crab harvest and protection from disturbance, initial results suggest that there has not been a noticeable recovery in the crab populations and hence egg availability (L.J. Niles, unpubl. data.). Given that horseshoe crabs do not attain sexual maturity until 8 - 9 years of age, it would appear that a recovery of the food resource would be unlikely in the near future, and could be difficult (Scheffer et al. 2005). It would therefore be anticipated that *rufa* knots, and the Florida/SE US and Maranhão, Brazil populations of *roselaari*, will continue to experience difficulty in Delaware Bay for some time. The much longer, time-constrained migration of the Tierra del Fuego knots compared to those wintering in Florida or northern Brazil appears to put them more at risk from the reduced food availability, and several studies have shown lower annual survival of the southern population (Harrington et al. 1988; Baker et al. 2004; Atkinson 2005).

Drastic reductions in crab numbers have also been reported in other areas (e.g., Cape Cod, Widener and Barlow 1999; see ASMFC 1998 for discussion). The widespread reductions in horseshoe crabs suggest that alternate suitable spring staging areas are much less available than before. Furthermore, there is some doubt that alternative food resources may be able to replace the loss of horseshoe crab eggs. Knots (*rufa* and other populations) generally feed on bivalves and other intertidal invertebrates during migration and winter (Bent 1927; Gonzalez et al. 1996; Harrington 2001; Harrington and Winn 2001; Truitt et al. 2001; Sitters 2005), but preliminary studies by Escudero and Niles (2001) have suggested that invertebrates in many Atlantic coast habitats may not, unlike horseshoe crab eggs, supply the energetic needs of knots on spring migration, a suggestion supported by observations of night feeding (Sitters 2001; Sitters et al. 2001).

One of the main threats to *C. c. islandica* populations appears to be the overharvesting of shellfish on the Dutch Wadden Sea. Here mechanical dredging has resulted in declines in availability of food for the birds, a situation somewhat analogous to that occurring in Delaware Bay for knots on migration in North America (van Gils et al. 2006).

Habitat loss and degradation

Extensive wetland losses in the USA have included the disappearance of almost half of the marshes extant in 1900 along the Atlantic and Gulf coasts (Dahl 1990, GLCF 2005). Loss rates in the North and mid Atlantic regions were high up to 1978 (Ducks Unlimited 2005), though have declined dramatically since protective legislation has been passed (Dahl and Johnson 1991; Dahl 2000; Ducks Unlimited 2005). Nevertheless, it is clear that a large portion of the previously available habitat has been altered or destroyed. This again suggests that knots faced with a decimated food resource in Delaware Bay now have many fewer alternative habitats that they can use, making population

recovery potentially much more difficult.

Spartina invasion of major migration habitats in WA state may have affected the Pacific coast population of *roselaari* knots, though *Spartina* has been cleared in recent years at a key stopover site (Grays Harbor).

Habitat degradation in wintering areas in the Dutch Wadden Sea may also threaten wintering populations of *islandica* (see above).

Disturbance

Numerous studies have shown that repeated disturbance can negatively affect shorebirds, disrupting behaviour patterns and affecting their energy balance (e.g., Davidson and Rothwell 1993; Gill et al. 2001; West et al. 2002). Although disturbance was initially a significant problem for shorebirds in Delaware Bay during spring migration (Burger et al. 1995; Sitters 2001), closure of major sections of the New Jersey shore since 2003 to human use at the peak of migration has successfully reduced disturbance (Burger et al. 2004; Niles et al. 2005).

In other parts of the range, disturbance can be a significant factor. Disturbance of roosting and feeding flocks by humans and dogs has been reported from Florida, Georgia, North Carolina, South Carolina, Virginia, and Massachusetts (Niles et al. 2005). On the wintering grounds in Tierra del Fuego, roosting flocks at Rio Grande are frequently disturbed by walkers, runners, fishermen, dogs, all-terrain vehicles, and motor cycles (Niles et al. 2005; RIGM pers. obs.). In Argentina, disturbance of knots on migration has been reported from Rio Gallegos, Peninsula Valdes, San Antonio Oeste, and Bahia Samborombon (Niles et al. 2005).

Severe weather events during migration

There has recently been a significant increase in the number and strength of hurricanes globally, including those occurring in the North Atlantic region (Webster et al. 2005) at times and in areas used by knots (RIGM unpubl. data). Whether knots have actually been affected is not known, but the increasing number of severe weather events during their southward migration across the North Atlantic certainly represents an increased risk, which is likely to increase with predictions of global warming and increasing ocean temperatures. Hurricanes, which could affect knots, have also recently been recorded in the southern Atlantic Ocean (TRMM 2005).

Oil pollution and other developments in North and South America

Extensive oil developments, with onshore and offshore wells, occur near major wintering areas of *rufa* knots in both the Chilean and Argentinean sectors of Tierra del Fuego, and represent a considerable potential for disaster (R.I.G. Morrison and R.K. Ross unpub. data). Two oil spills from shipping have been recorded near the Strait of Magellan First Narrows (Niles et al. 2005) and small amounts of oil have been noted on

knots captured during banding operations in Bahia Lomas (A. Dey and L.J. Niles unpubl. data). Over the past 8 - 10 years, oil operations have been decreasing in Chile near Bahia Lomas and increasing on the Atlantic coast of Tierra del Fuego. Petroleum exploration, mangrove clearance, and iron ore and gold mining, which can result in oil and mercury pollution and habitat loss, are important threats on the north-central coast of Brazil and could affect the Maranhão/Brazil population of *roselaari* (Niles et al. 2005).

The important migration stopover area at San Antonio Oeste, Argentina, also faces potential pollution from a soda ash factory (which could release up to 250,000 tons or more of calcium chloride per year, affecting intertidal invertebrate food supplies) and from port activities (e.g., pollution from shipping).

In North America, important estuarine areas such as Delaware Bay and the Gulf of St. Lawrence are at risk from pollution and shipping incidents. The Mingan Islands, in the St. Lawrence, are particularly at risk because large ships carrying titanium and iron navigate through the archipelago to the Havre-St-Pierre harbour throughout the year (Y. Aubry pers. comm. 2007). Some additional large scale developments that could have a major impact on important shorebird migration areas include tidal power in the Bay of Fundy, plans for which have recently been resurrected (CBC 2005). Also, barging has been proposed in connection with diamond mining developments near Attawapiskat on the west coast of James Bay, which could affect the river mouth habitats (W. Crins pers. comm. 2007).

Developments in California (e.g., San Francisco Bay) and Mexico and along the migration route of the Pacific coast population of *roselaari* could potentially affect wintering and migrating birds, respectively.

Climate change: Arctic breeding grounds

The Arctic is one of the regions most likely to be affected by climate change (ACIA 2004). Meltofte et al. (2005) have provided a detailed review of potential effects of climate change in the Arctic on shorebirds; major concerns include changes in habitat, especially long-term reductions in High Arctic habitats, and uncoupling of phenology of food resources and breeding events. As the High Arctic zone is expected to shift northwards, Red Knots, as High Arctic breeders, are likely to be among the species most affected. This would be particularly the case for populations breeding towards the southern part of the High Arctic zone, such as *rufa* breeding in the central Canadian Arctic.

Climate change: sea level rise and loss of coastal habitat

Potential losses of intertidal habitats owing to sea level rise was projected to range between 20% and 70% during the next century at five major sites in the USA, including Delaware Bay (60%; Galbraith et al. 2002). While detailed effects are difficult to predict (IPCC 2001), the authors concluded that the scale of the losses cast serious doubts on the ability of the sites to continue supporting current numbers of shorebirds, indicating

increased future stress on knot populations.

Disease and parasites

Piersma (1997, 2003) pointed out that long-distance shorebird migrants, such as knots, occupy relatively parasite-free salt water habitats, possibly reflecting a trade-off between the requirements of an energetically and physiologically demanding lifestyle and a reduced need for a highly developed immune system. Shorebirds inhabiting freshwater (parasite and disease rich) habitats tend to have higher parasite loads (Figuerola 1999; Mendes et al. 2005). The occurrence of parasites or disease amongst long-distance shorebird migrants including knots has been recorded in Brazil (Baker et al. 1998; Araújo et al. 2003, 2004; see Niles et al. 2005; Baker 2005), Uruguay (Niles et al. 2005), Florida (Woodward et al. 1977; Forrester and Humphrey 1981), and Delaware (Southeastern Cooperative Wildlife Disease Study 2002; Niles et al. 2005). The poor condition of Red Knots in Delaware Bay and northern Brazil in recent years (Baker et al. 2004, 2005a) suggests that they may be at an elevated risk of disease or parasitic infection, since birds in poor condition as indicated by low body mass are more prone to infection by parasites and pathogens (Booth et al. 1993).

Predation.

Shorebirds have enjoyed what Butler et al. (2003) termed something of a “predator vacuum” over the past 30 years, arising from greatly depleted raptor populations caused by persecution and pesticide poisoning. Whether increasing predation from raptors has affected knots is unclear, but any recovery of the population will take place in a situation with increased numbers of avian predators (see predation section). Human hunting of shorebirds including knots may occur in some areas, including Caribbean islands and north-central Brazil, though this practice is thought to have decreased greatly in the latter area over the past decade (Serrano pers. comm. in Niles et al. 2005).

SPECIAL SIGNIFICANCE OF THE SPECIES

Red Knots have been regarded as a flagship species for shorebird conservation for many years, certainly well before the present concern over their declines. The reasons for this are based on the characteristics of their life style, particularly their enormously long, inter-hemispheric migrations, and their concentration in large numbers (involving substantial proportions of the population) at a limited number of key sites. These features in many ways make them an “arch-typical” shorebird, a species where conservation of its key habitats will also bring benefits to many other species of shorebirds and other waterbirds. At some sites, knots (and other shorebirds) may be economically important in attracting eco-tourists and birdwatchers.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

The Red Knot *rufa* subspecies has been designated a “candidate” species for Endangered Species Act protection by the USF&WS. This decision acknowledges that protection of the Red Knot is warranted but precluded by other, higher priority activities. The Red Knot was the subject of a petition to the US Fish and Wildlife Service to list the species as endangered and a request for an emergency listing under the Endangered Species Act (Delaware Riverkeeper Network et al. 2005). In the USA, the Red Knot *rufa* subspecies is listed as Threatened in the state of New Jersey and as a species of Special Concern in Georgia (Niles et al. 2005). In 2004, the Canadian Arctic-Atlantic Coast population of Red Knots was listed as Highly Imperiled in an update to shorebirds considered of High Priority in the U.S. Shorebird Conservation Plan (US Shorebird Conservation Plan 2004).

In 2005, *rufa* was added to Appendix 1 of the Convention on Migratory Species (CMS, or “Bonn” Convention; CMS 2005); this Appendix I lists migratory species threatened with extinction. The NatureServe website (October 2005) listing the population of *C. c. rufa*, globally as G4T1, or critically imperiled globally at the subspecies level, and nationally as N1N, or critically imperiled in its non-breeding range in the USA, and as N1B and N1N, or critically imperiled in both the breeding and non-breeding ranges in Canada (NatureServe 2006). Individual state and provincial/territorial assessments listed by NatureServe are shown in Table 4.

Table 4. NatureServe categories for Red Knots *rufa* subspecies in US States and Canadian Provinces (NatureServe 2006).

Category	USA, no. of states	Canada: no of provinces or territories
S1: critically imperiled	4 (DC, OK, VA, WI)	
S2: imperiled	5 (AK, DE, MA, MS, TN)	2 (NB, PE)
S3: vulnerable	8 (AL, GA, ME, NJ, NC, RI, TX, WA)	3 (NL, NS)
S4: apparently secure	2 (LA, WY)	
S5: secure	1 (OR)	1 (SK)
Other: not applicable, etc.	22 (AR, CA, CO, CT, FL, IL, IN, KS, KY, MD, MI, MN, MO, NE, NH, NY, ND, OH, PA, SC, SD, UT)	7 (AB, BC, MN, NT, NU, ON, QC)

The IUCN Red List of Threatened Species lists Red Knots on a worldwide basis as being of Least Concern (BirdLife International 2004), but this assessment clearly does not take into account the status of the various subspecies and biogeographic units of Red Knots and is thus of very limited use in terms of conservation of biodiversity on a national, state, provincial, or regional level. *C. c. islandica* is given an Amber listing in the U.K., Concern listing in Europe and Least Concern listing Globally by the British Trust for Ornithology.

TECHNICAL SUMMARY

Calidris canutus rufa

Red Knot, *rufa* subspecies

Bécasseau maubèche, sous-espèce *rufa*

Range of Occurrence in Canada:
NU, NT, BC, AB, SK, MB, ON, QC, NB, NS, PE, NL

Extent and Area Information	
<ul style="list-style-type: none"> • <i>Extent of occurrence (EO)(km²)</i> Area of breeding range derived from information compiled from distribution maps 	205,534 km ² (breeding)
<ul style="list-style-type: none"> • <i>Specify trend in EO</i> 	Unknown
<ul style="list-style-type: none"> • <i>Are there extreme fluctuations in EO?</i> 	No
<ul style="list-style-type: none"> • <i>Area of occupancy (AO) (km²)</i> Based on area of suitable habitat on classified land cover maps 	128,375 km ² (breeding)
<ul style="list-style-type: none"> • <i>Specify trend in AO</i> 	Probably stable on breeding grounds
<ul style="list-style-type: none"> • <i>Are there extreme fluctuations in AO?</i> 	No
<ul style="list-style-type: none"> • <i>Number of known or inferred current locations</i> 	N/A
<ul style="list-style-type: none"> • <i>Specify trend in #</i> 	N/A
<ul style="list-style-type: none"> • <i>Are there extreme fluctuations in number of locations?</i> 	N/A
<ul style="list-style-type: none"> • <i>Specify trend in area, extent or quality of habitat</i> 	Probably stable on breeding grounds Decrease in migration habitat

Population Information	
<ul style="list-style-type: none"> • <i>Generation time (average age of parents in the population)</i> 	4-5 years
<ul style="list-style-type: none"> • <i>Number of mature individuals</i> 	13,500 – 15,000
<ul style="list-style-type: none"> • <i>Total population trend:</i> 	Decline
<ul style="list-style-type: none"> • <i>% decline over the last/next 10 years or 3 generations.</i> 15 year (three generations) trend calculated over entire wintering area in Tierra del Fuego and Patagonia 	70.5%
<ul style="list-style-type: none"> • <i>Are there extreme fluctuations in number of mature individuals?</i> 	No
<ul style="list-style-type: none"> • <i>Is the total population severely fragmented?</i> 	No
<ul style="list-style-type: none"> • <i>Specify trend in number of populations</i> 	N/A
<ul style="list-style-type: none"> • <i>Are there extreme fluctuations in number of populations?</i> 	N/A
<ul style="list-style-type: none"> • List populations with number of mature individuals in each: 	

Threats (actual or imminent threats to populations or habitats)
<ul style="list-style-type: none"> • reduction in major food supply (eggs of horseshoe crab) in Delaware Bay on northward migration, • habitat loss (coastal wetlands) along migration routes. • other threats include changing weather patterns (increased hurricanes and tropical storms), pollution, disturbance

Rescue Effect (immigration from an outside source)	No
<ul style="list-style-type: none"> • <i>Status of outside population(s)?</i> USA: (Not applicable). 	
<ul style="list-style-type: none"> • <i>Is immigration known or possible?</i> No interchange has been detected between main biogeographic groups wintering in The Americas. 	Not known
<ul style="list-style-type: none"> • <i>Would immigrants be adapted to survive in Canada?</i> 	Not applicable
<ul style="list-style-type: none"> • <i>Is there sufficient habitat for immigrants in Canada?</i> 	Not applicable
<ul style="list-style-type: none"> • <i>Is rescue from outside populations likely?</i> Repopulation from other biogeographic groups of knots would not be anticipated. 	No

Quantitative Analysis	
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Current Status	COSEWIC: None
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Author of Technical Summary: Dr. R.I.G. Morrison, December 2005, revised November 2006; Marty Leonard, February 2007
Additional Sources of Information: Information sources in report.

Recommended Status and Reasons for Designation

Recommended Status: Endangered	Alpha-numeric code: Meets Endangered A2a
Reasons for Designation: This subspecies has shown a 70% decline in abundance over the past three generations. It continues to be threatened by a depletion in horseshoe crab eggs, a critical food source used during migration. There is no potential for rescue from other populations.	
Applicability of Criteria Criterion A (Declining Total Population): Meets Endangered A2a because population has declined by 70% in three generations Criterion B (Small Distribution, and Decline or Fluctuation): Does not meet criterion Criterion C (Small Total Population Size and Decline): Does not meet criterion Criterion D (Very Small Population or Restricted Distribution): Does not meet criterion Criterion E (Quantitative Analysis):	

TECHNICAL SUMMARY

Calidris canutus roselaari

Red Knot, *roselaari* subspecies

Bécasseau maubèche, sous-espèce
roselaari

Range of Occurrence in Canada:
BC, YK, NWT

Extent and Area Information	
<ul style="list-style-type: none"> • <i>Extent of occurrence (EO)(km²)</i> Breeding area derived from information compiled from distribution maps 	<p>Florida/SE US and Maranhão: unknown</p> <p>Pacific coast: 41,396 km²</p>
<ul style="list-style-type: none"> • <i>Specify trend in EO</i> 	<p>Unknown</p>
<ul style="list-style-type: none"> • <i>Are there extreme fluctuations in EO?</i> 	<p>No</p>
<ul style="list-style-type: none"> • <i>Area of occupancy (AO) (km²)</i> Based on area of suitable habitat in breeding area on classified land cover maps 	<p>Florida/SE US and Maranhão: unknown "</p> <p>Pacific coast: 25,856 km²</p>
<ul style="list-style-type: none"> • <i>Specify trend in AO</i> 	<p>Stable on breeding grounds</p>
<ul style="list-style-type: none"> • <i>Are there extreme fluctuations in AO?</i> 	<p>No</p>
<ul style="list-style-type: none"> • <i>Number of known or inferred current locations</i> 	<p>N/A</p>
<ul style="list-style-type: none"> • <i>Specify trend in #</i> 	<p>N/A</p>
<ul style="list-style-type: none"> • <i>Are there extreme fluctuations in number of locations?</i> 	<p>No</p>
<ul style="list-style-type: none"> • <i>Specify trend in area, extent or quality of habitat</i> 	<p>Probably stable on breeding grounds</p> <p>Decrease on migration routes and some wintering sites</p>

Population Information	
<ul style="list-style-type: none"> • <i>Generation time (average age of parents in the population)</i> 	<p>4-5 years</p>
<ul style="list-style-type: none"> • <i>Number of mature individuals</i> Florida/SE US: 3,375, Maranhão: 5,700, Pacific coast: 1,500-3,000 	<p>Combined population: 12,825</p>
<ul style="list-style-type: none"> • <i>Total population trend:</i> 	<p>Florida/SE US: decline Maranhão: stable (?) – decline Pacific coast: decline</p>
<p><i>% decline over the last/next 10 years or 3 generations</i> 15 years (three generations) trend calculated on the wintering areas Florida/SE US: 70%, Maranhão: 7% (?), Pacific coast: 60% (see text for calculation)</p>	<p>Combined trend: 47%</p>
<ul style="list-style-type: none"> • <i>Are there extreme fluctuations in number of mature individuals?</i> 	<p>No</p>

• <i>Is the total population severely fragmented?</i>	No
• <i>Specify trend in number of populations</i>	Not applicable
• <i>Are there extreme fluctuations in number of populations?</i>	Not applicable
• List populations with number of mature individuals in each: see above	

Threats (actual or imminent threats to populations or habitats)
<p>Florida/SE US and Maranhão:</p> <ul style="list-style-type: none"> - reduction in major food supply (eggs of horseshoe crab) in Delaware Bay on northward migration - habitat reductions (coastal wetlands) along migration routes - degradation of wintering sites in Florida through development Pacific coast: - developments in California (e.g., San Francisco Bay) affecting wintering and migrating birds - habitat degradation along migration routes <p>- other threats include changing weather patterns (increased hurricanes and tropical storms), pollution, disturbance</p>

Rescue Effect (immigration from an outside source)	No
<ul style="list-style-type: none"> • <i>Status of outside population(s)?</i> USA: (Not applicable). 	
<ul style="list-style-type: none"> • <i>Is immigration known or possible?</i> No interchange has been detected between main biogeographic groups wintering in The Americas. 	Not known
<ul style="list-style-type: none"> • <i>Would immigrants be adapted to survive in Canada?</i> 	Not applicable
<ul style="list-style-type: none"> • <i>Is there sufficient habitat for immigrants in Canada?</i> 	Not applicable
<ul style="list-style-type: none"> • <i>Is rescue from outside populations likely?</i> Repopulation from other biogeographic groups of knots would not be anticipated. 	No

Quantitative Analysis No analyses available	Not available
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Current Status COSEWIC: None
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Author of Technical Summary: Dr. R.I.G. Morrison, December 2005, revised November 2006; Marty Leonard, February 2007
 Additional Sources of Information: Information sources in report.

Recommended Status and Reasons for Designation

Recommended Status: Threatened	Alpha-numeric code: Meets Threatened A2a
Reasons for Designation: This group has declined by 47% overall during the last three generations. Ongoing threats include habitat loss and degradation on wintering sites and, for the Florida/SE US and Maranhão groups, depleted levels of horseshoe crab eggs, a critical food source needed during migration. Rescue from other populations is not anticipated	

Applicability of Criteria

Criterion A (Declining Total Population): Meets Threatened A2a because population has declined by 47% over the last three generations

Criterion B (Small Distribution, and Decline or Fluctuation): Does not meet criterion

Criterion C (Small Total Population Size and Decline): Does not meet criterion

Criterion D (Very Small Population or Restricted Distribution): Does not meet criterion

Criterion E (Quantitative Analysis):

TECHNICAL SUMMARY

Calidris canutus islandica

Red Knot, *islandica* subspecies

Bécasseau maubèche, sous-espèce
islandica

Range of Occurrence in Canada: NU

Extent and Area Information	
<ul style="list-style-type: none"> • <i>Extent of occurrence (EO)(km²)</i> Area of breeding range in Canada derived from information compiled from distribution maps 	455,669 km ²
<ul style="list-style-type: none"> • <i>Specify trend in EO</i> 	Unknown
<ul style="list-style-type: none"> • <i>Are there extreme fluctuations in EO?</i> 	No
<ul style="list-style-type: none"> • <i>Area of occupancy (AO) (km²)</i> Based on area of suitable habitat in breeding grounds in Canada on classified land cover maps 	284,611 km ²
<ul style="list-style-type: none"> • <i>Specify trend in AO</i> 	Probably stable on Canadian breeding grounds
<ul style="list-style-type: none"> • <i>Are there extreme fluctuations in AO?</i> 	No
<ul style="list-style-type: none"> • <i>Number of known or inferred current locations</i> 	N/A
<ul style="list-style-type: none"> • <i>Specify trend in #</i> 	N/A
<ul style="list-style-type: none"> • <i>Are there extreme fluctuations in number of locations?</i> 	N/A
<ul style="list-style-type: none"> • <i>Specify trend in area, extent or quality of habitat</i> 	Probably stable on breeding grounds Decrease in wintering areas

Population Information	
<ul style="list-style-type: none"> • <i>Generation time (average age of parents in the population)</i> 	4-5 years
<ul style="list-style-type: none"> • <i>Number of mature individuals</i> 81,000: based on 40% of total breeding population (202,500) in Canada 	81,000
<ul style="list-style-type: none"> • <i>Total population trend:</i> 	decline
<ul style="list-style-type: none"> • <i>% decline over the last/next 10 years or 3 generations.</i> Trend between 1998 and 2003, although likely similar over the last 15 years (3 generations) 	17%
<ul style="list-style-type: none"> • <i>Are there extreme fluctuations in number of mature individuals?</i> 	No
<ul style="list-style-type: none"> • <i>Is the total population severely fragmented?</i> 	No
<ul style="list-style-type: none"> • <i>Specify trend in number of populations</i> 	Not applicable
<ul style="list-style-type: none"> • <i>Are there extreme fluctuations in number of populations?</i> 	Not applicable
<ul style="list-style-type: none"> • <i>List populations with number of mature individuals in each: see above</i> 	

Threats (actual or imminent threats to populations or habitats)	
<ul style="list-style-type: none"> • overharvesting of shellfish on Dutch Wadden Sea • habitat degradation in wintering areas 	
Rescue Effect (immigration from an outside source)	Possible

<ul style="list-style-type: none"> • <i>Status of outside population(s)?</i> Declining in Europe [other jurisdictions or agencies] (Not applicable). 	
<ul style="list-style-type: none"> • <i>Is immigration known or possible?</i> 	Possible
<ul style="list-style-type: none"> • <i>Would immigrants be adapted to survive in Canada?</i> 	Yes
<ul style="list-style-type: none"> • <i>Is there sufficient habitat for immigrants in Canada?</i> 	Yes
<ul style="list-style-type: none"> • <i>Is rescue from outside populations likely?</i> 	Possible rescue from breeding populations in Greenland

Quantitative Analysis	
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Current Status	COSEWIC: None
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Author of Technical Summary: Dr. R.I.G. Morrison, December 2005, revised November 2006; Marty Leonard February 2007
 Additional Sources of Information: Information sources in report.

Recommended Status and Reasons for Designation

Recommended Status: Special Concern	Alpha-numeric code: None
<p>Reasons for Designation: This subspecies has declined by 17% over the last three generations. Although habitat on the Canadian breeding grounds is likely stable, shellfish harvesting on the wintering grounds in Europe presents an ongoing threat.</p>	
<p><u>Applicability of Criteria</u></p> <p>Criterion A (Declining Total Population): Does not meet criterion</p> <p>Criterion B (Small Distribution, and Decline or Fluctuation): Does not meet criterion</p> <p>Criterion C (Small Total Population Size and Decline): Does not meet criterion</p> <p>Criterion D (Very Small Population or Restricted Distribution): Does not meet criterion</p> <p>Criterion E (Quantitative Analysis):</p>	

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Allen J. Baker is Head of the Centre for Biodiversity and Conservation Biology at the Royal Ontario Museum, Toronto, ON. Patricia M. Gonzalez is a prominent conservationist and researcher on Red Knots in South America and is a partner with Fundacion Inalafquen, San Antonio Oeste, Argentina. Larry J. Niles is the Chief of the Endangered and Nongame Species Program with the New Jersey Division of Fish and Wildlife. R. Ken Ross is a biologist with the Canadian Wildlife Service, Ontario Region in Ottawa, and with Guy Morrison has carried out all the CWS Shorebird Atlas Projects in South America, Central America, and Panama.

COLLECTIONS EXAMINED

No collections were examined during the course of writing this report.